EXHIBIT Q

BUREAU OF RECLAMATION

2020 Seasonal Report for the Shasta Cold Water Pool Management

Central Valley Project, California
California-Great Basin Region

U.S. Department of the Interior **December 2020**

Mission Statements

The Department of the Interior (DOI) conserves and manages the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provides scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

2020 Seasonal Report for the Shasta Cold Water Pool Management

Central Valley Project, California
California-Great Basin Region

prepared by

Central Valley Operations Office
3310 El Camino Avenue, Suite 300
Sacramento, CA 95821

Bay-Delta Office
801 "I" Street, Suite 140
Sacramento, CA 95814

in coordination with CDFW, DWR, USFWS, and NMFS

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Purpose

This 2020 Seasonal Report for Shasta Cold Water Pool Management describes Shasta Dam operations leading up to and through the 2020 cold water pool management season. This seasonal report may support improvements, if necessary, to the Shasta Cold Water Pool Management Guidance Document, and may also guide operations in the future. This seasonal report fulfills commitments under the Record of Decision (ROD) signed by Reclamation for the Reinitiation of Consultation on the Coordinated Long-Term Operations of the Central Valley Project (CVP) and State Water Project (SWP) to produce a Seasonal Report for Shasta Cold Water Pool by the end of December of each year. Additionally, this seasonal report will be used to support the development of Reclamation's Annual Summary of Water Supply and Fish Operations (Annual Report). Finally, this document will inform the Four-Year Review Panels adopted under the ROD. The purpose of the independent review will be to evaluate the efficacy of actions undertaken to reduce the adverse effects on listed species.

Compliance with the National Marine Fisheries Service (NMFS) and the United States Fish and Wildlife Service (USFWS) 2019 Biological Opinions' Reasonable and Prudent Measures and associated Terms and Conditions adopted by the aforementioned ROD will be documented and discussed in the Annual Report and not in this document. Although this document strives to provide an integrated view of the system and the factors affecting the coordinated operation of the CVP and SWP, evaluation and discussion is focused on actions taken specifically by Reclamation for Shasta Lake's cold water pool management.

Background

Shasta Dam and Lake represent about 40 percent of the total reservoir storage capacity of the CVP and are located in northern California near Redding (Figure 1). Reclamation operates Shasta Dam in coordination with state and federal fishery agencies (NMFS, USFWS, and California Department of Fish and Wildlife (CDFW)), the State Water Resources Control Board (SWRCB), tribal entities, Western Area Power Administration, water contractors and other stakeholders, and in conjunction with other CVP facilities to provide for the management of floodwater, storage of winter runoff for irrigation in the Sacramento and San Joaquin valleys, Municipal and Industrial (M&I) water supply, maintenance of navigation flows, protection of fish in the Sacramento River and Delta, and hydropower generation.

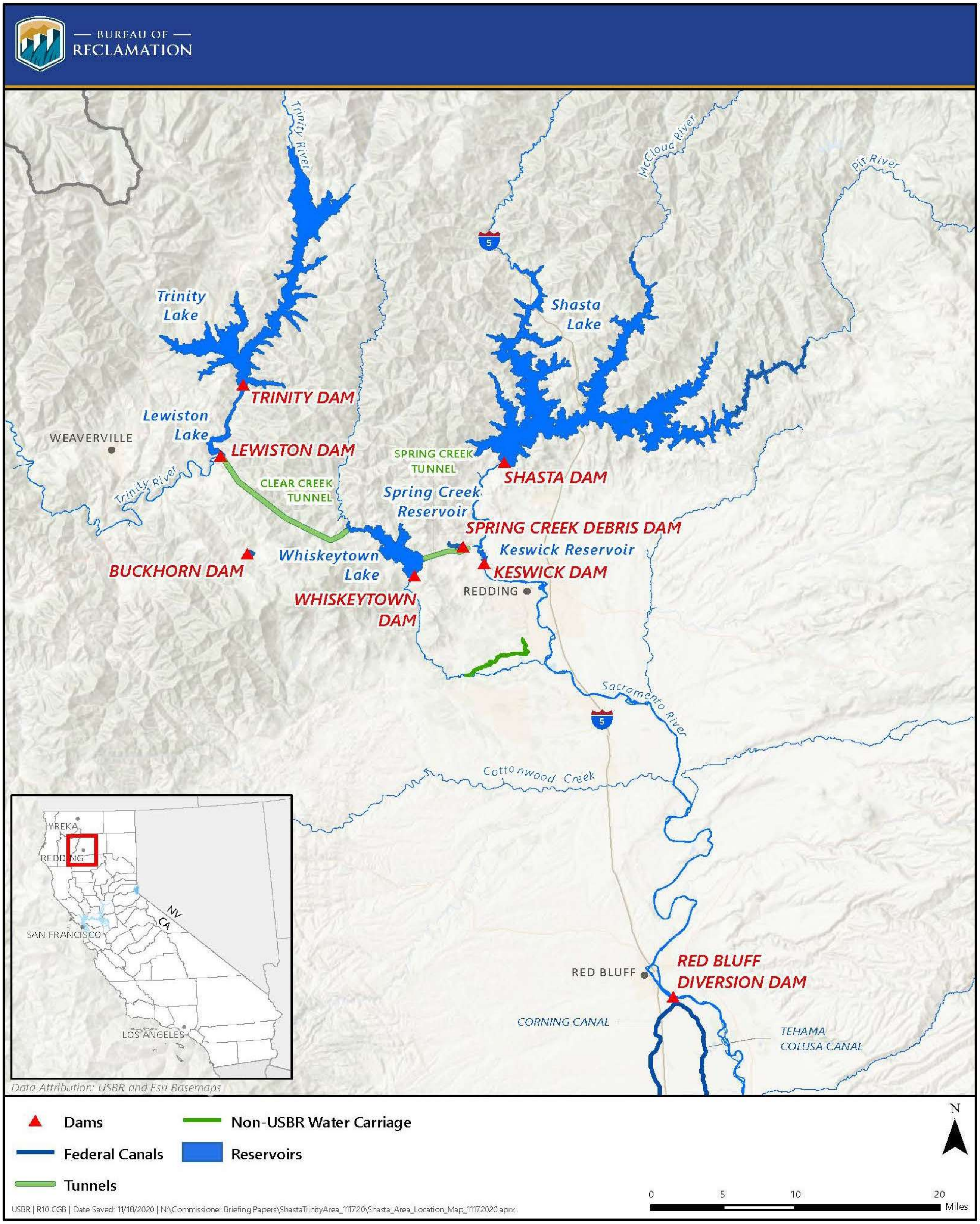

Figure 1. Shasta-Trinity System located in Northern California.

Reclamation consulted under the Endangered Species Act (ESA) with the USFWS and NMFS on potential effects of the Proposed Action on threatened and endangered species. Reclamation submitted to these agencies a Biological Assessment on January 31, 2019. Reclamation provided the final Biological Assessment on October 21, 2019, which included the final Proposed Action description. In turn, the USFWS and NMFS issued their Biological Opinions of the Proposed Action on October 21, 2019. Previously, management of the CVP and SWP operations was in part governed by the Biological Opinions provided in 2008 (USFWS) and 2009 (NMFS). The Shasta Cold Water Pool Management is a part of the Upper Sacramento Operations described in the Proposed Action. Reclamation signed the ROD, which included the 2019 Biological Opinions from USFWS and NMFS and began implementing the Proposed Action on February 18, 2020.

The ROD identified the following operational components to increase spring Shasta Lake storage levels: (1) Fall and Winter Refill and Redd Maintenance, which sets minimum late fall and winter flows, including coordination on rice decomposition operations; (2) a summer-fall Delta Smelt habitat action that prioritizes meeting Delta outflow requirements through export management; (3) flexibility in late-winter and spring export operations (especially in April and May); and (4) December 2018 changes to COA. The ROD includes consideration of releasing spring pulse flows of up to 150 thousand acre-feet (TAF) to support the migration of Chinook salmon subject to whether the projected total May 1 Shasta Lake storage indicates a likelihood of sufficient cold water to support summer cold water pool management, and the pulse does not interfere with the ability to meet performance objectives or other anticipated demands on the reservoir.

The ROD established a tiered cold water management strategy for the summer and fall seasons, based on the projected availability of cold water pool. The approach considers meteorology, Delta conditions, and habitat suitability for incoming fish population size and location to determine a pattern of water temperature targets for winter-run Chinook salmon redds. The tiered strategy recognizes that cold water is a scarce resource that can be managed to achieve desired water temperatures for winter-run Chinook salmon egg-to-fry survival.

The Shasta Cold Water Pool Management Guidance Document (Appendix A) provides implementation guidance on the Sacramento River's Cold Water Pool Management pursuant to the ROD. The scope of guidance includes the deliverables, schedule, and processes of different teams to implement operations for Cold Water Pool Management. The primary deliverables are Sacramento River Temperature Task Group (SRTTG) notes, a monthly summary of the hydrologic, operational, and water temperature data related to cold water pool management; the Sacramento Temperature Management Plan (TMP), and documentation of the operations decisions. It is expected Reclamation will manage requirements of the California State Water Resources Control Board (SWRCB) Decision 90-5 separately.

SWRCB Water Rights Order 90-5 influences operations establishing a requirement for Reclamation to operate Keswick Dam, Shasta Dam, Spring Creek Power Plant, and the Trinity River Division to meet a daily average water temperature of 56°F on the Sacramento River at Red Bluff Diversion Dam (RBDD) during periods when higher water temperatures will be detrimental to fish.

Seasonal Operations

WY 2020 was a dry year with below average precipitation in several months, particularly in late winter and early spring. In February, water temperature performance for the year was estimated to be approximately between 54°F-56°F at the Sacramento River above Clear Creek gage (CCR) based on projected May 1 total Shasta Dam storage and projected cold water pool conditions; in March water temperature performance for the year was estimated to be poorer than approximately 54°F-56°F at CCR. Because of lower than average precipitation, a Shasta Critical Year determination was made on April 13, 2020. Development of Temperature Management Plan involves Temperature Tier selection, which can be based on total Shasta Lake storage volume, Shasta Lake cold water pool volume, or water temperature modeling results. In WY 2020, modeling determined the tier selection. Temperature Tier 3 was selected for the Temperature Management Plan based on water temperature modeling results and Reclamation began implementing the final Temperature Management Plan on May 15, 2020. May precipitation was almost double the average (average May precipitation was 2.2 inches; WY 2020 precipitation was 4.3 inches). A Shasta Non-Critical determination was made on June 8, 2020 based on DWR Bulletin 120 Forecast Update June 2, 2020. June precipitation was again below average. Unusually warm air temperature conditions were also noted this year as well as prolonged smoke and haze as a result of large, widespread, and persistent regional fires. Highly variable warming and cooling trends again challenged water temperature management. The water temperature management season ended on October 31, 2020; the daily average water temperature performance exceedances for CCR and BSF compliance locations compared against the daily target are shown in Table 4 of this section.

Operational Background Information

This section describes the 2020 ROD commitments, including guidance on how Reclamation manages the cold water pool in Shasta Lake and the development of the Temperature Management Plan. Additionally, a historical overview of climatic conditions is summarized.

Commitments of the 2020 ROD

Shasta Lake storage at the end of May affects Reclamation's ability to meet the 53.5°F water temperature target on the Sacramento River above Clear Creek for winter-run Chinook salmon spawning and egg incubation throughout the water temperature management season. A greater storage volume minimizes risks of higher water temperatures in the upper Sacramento River in the late summer and fall. The approximate relationship between water temperature compliance, total storage in Shasta Lake, and cold water pool in Shasta Lake is shown in Figure 2.

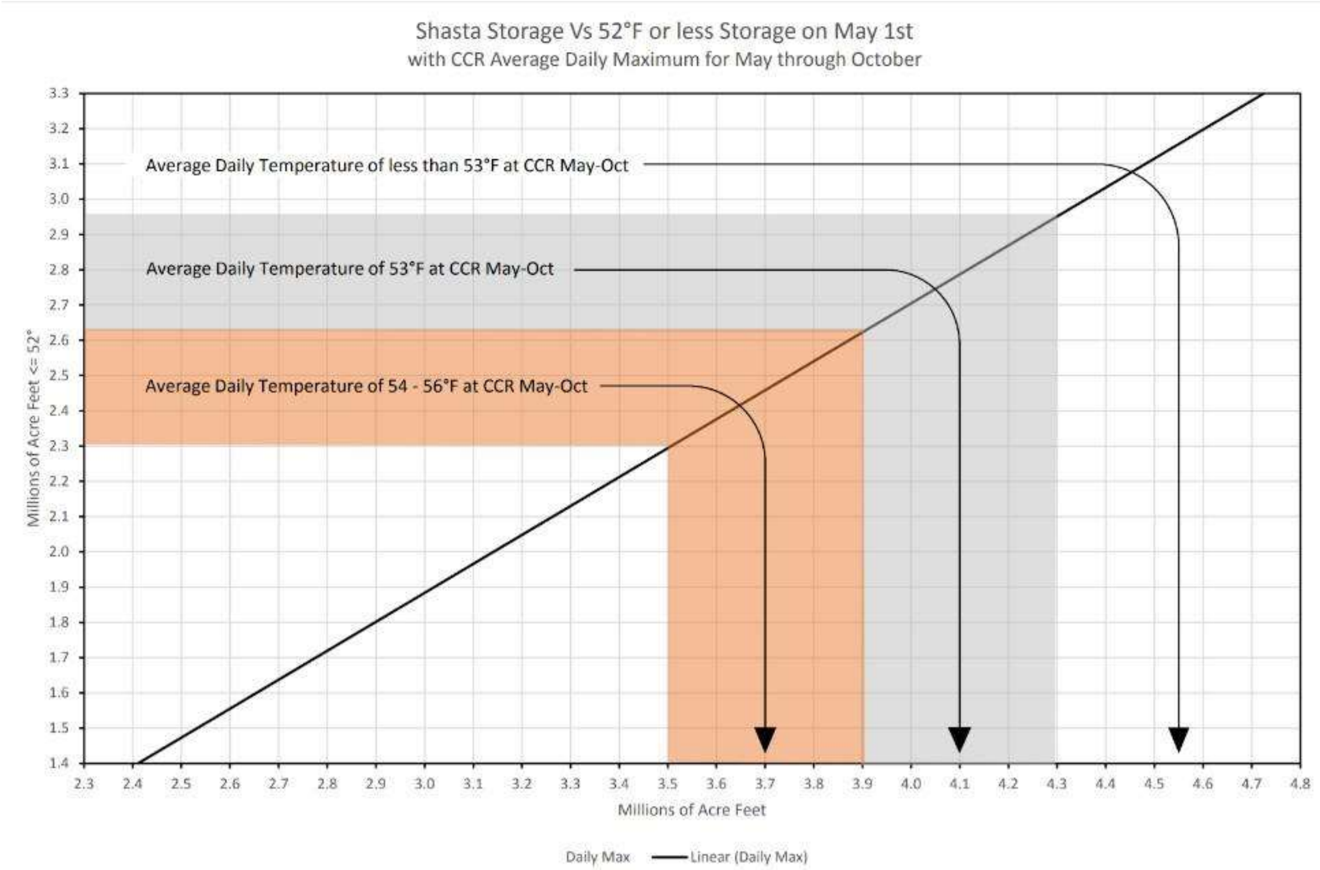

Figure 2. Relationship between water temperature compliance, total storage in Shasta Lake, and cold water pool in Shasta Lake.

Reclamation addresses cold water management utilizing a tiered strategy that allows for strategically selected water temperature objectives, based on projected total storage and cold water pool, meteorology, Delta conditions, and habitat suitability for incoming fish population size and location. Reclamation manages water temperatures based on the following tiers, depending on the actual size of the cold water pool in a given year:

- Tier 1 – Sufficient volume of cold water to targets 53.5°F or lower starting May 15 through October 31
- Tier 2 – Sufficient volume of cold water to target 53.5°F during critical egg incubation period
- Tier 3 – A volume of cold water that can target 53.5-56°F during critical egg incubation period; and consideration of intervention measures in lower Tier 3 years
- Tier 4 – Insufficient cold water to maintain 56°F or lower; and consideration of intervention measures

Reclamation is required to develop a Temperature Management Plan to describe how Reclamation plans to operate Shasta Lake and the Temperature Control Device (TCD) on Shasta Dam consistent with the 2020 ROD. Reclamation utilizes a conservative forecast in seasonal planning of reservoir releases (including developing initial and updated allocations) and temperature management planning, such that monthly release forecasts and associated allocations are typically based on a 90

percent exceedance inflow forecast through September. Reclamation's TMP uses modeling and professional expertise to identify the most protective tier that can be achieved given the available cold water. Before the reservoir stratifies and the volume of cold water is known, Reclamation estimates temperature capabilities based on projections of storage.

Reclamation convened SRTTG meetings, starting in February, on a monthly basis to ensure communication and coordination among the parties in preparation for the temperature management season; SRTTG meeting notes can be found at: https://www.usbr.gov/mp/bdo/water-year-2020-rivertask.html. Reclamation prepared projections of anticipated temperature management capabilities on a monthly timestep to the SRTTG. In mid-February, Reclamation prepared initial projections of anticipated temperature management capability and considerations based on the February hydrologic and runoff forecasts from the Department of Water Resources and National Weather Service River Forecast Center. Reclamation's February projections showed that a potential Tier 3 year was possible, but that below normal hydrology also made a Tier 4 year a possibility. Reclamation initiated interagency coordination through the Drought and Dry Year activities and stakeholder coordination through the Meet and Confer activities described in the 2020 ROD.

Reclamation drafted a preliminary draft TMP and submitted it to the SRTTG on April 23 for initial review, comment, and discussion. The draft TMP balanced the most protective possible temperature tier with what is achievable and sustainable with the volume of available cold water pool for the duration of the temperature control period through October 31, 2020.

On May 20, 2020, Reclamation developed a final TMP (Appendix B) with substantial coordination and input from the SRTTG. The TMP included temperature locations and targets through October 31, modeled winter-run Chinook salmon egg mortality, dates for operation of the side gates on the TCD, and the end of September cold water pool. Further discussion of the final TMP is provided below in the Summer/Fall Water Temperature Management section.

Historical Overview

Historic Shasta Lake storage volume (WY 2000 – 2020) is shown in Figure 3. In WY 2020, end of May Shasta Lake storage volume was higher than the historic 20-year average (2000 – 2020 average: 3.3 million acre-feet (MAF); 2020 value: 3.5 MAF). Historic daily average air temperatures at Shasta Dam (2000 – 2020) is shown in Figure 4. According to the National Weather Service, Redding, California experienced above average air temperatures in the summer of 2020 (June 1st – August 31st), with August 2020 being the fifth warmest month on record (1893 – 2020). The mean monthly temperature of October 2020 was characterized as much above normal or as the record warmest in northern California (Figure 4). Widespread wildfire activity throughout the summer impacted local meteorological conditions including solar radiation and thermal influences. Smoke and haze were unusually prevalent throughout August and September and likely dampened the effects of unusually warm air temperature conditions on reservoir heating and downstream in-river warming.

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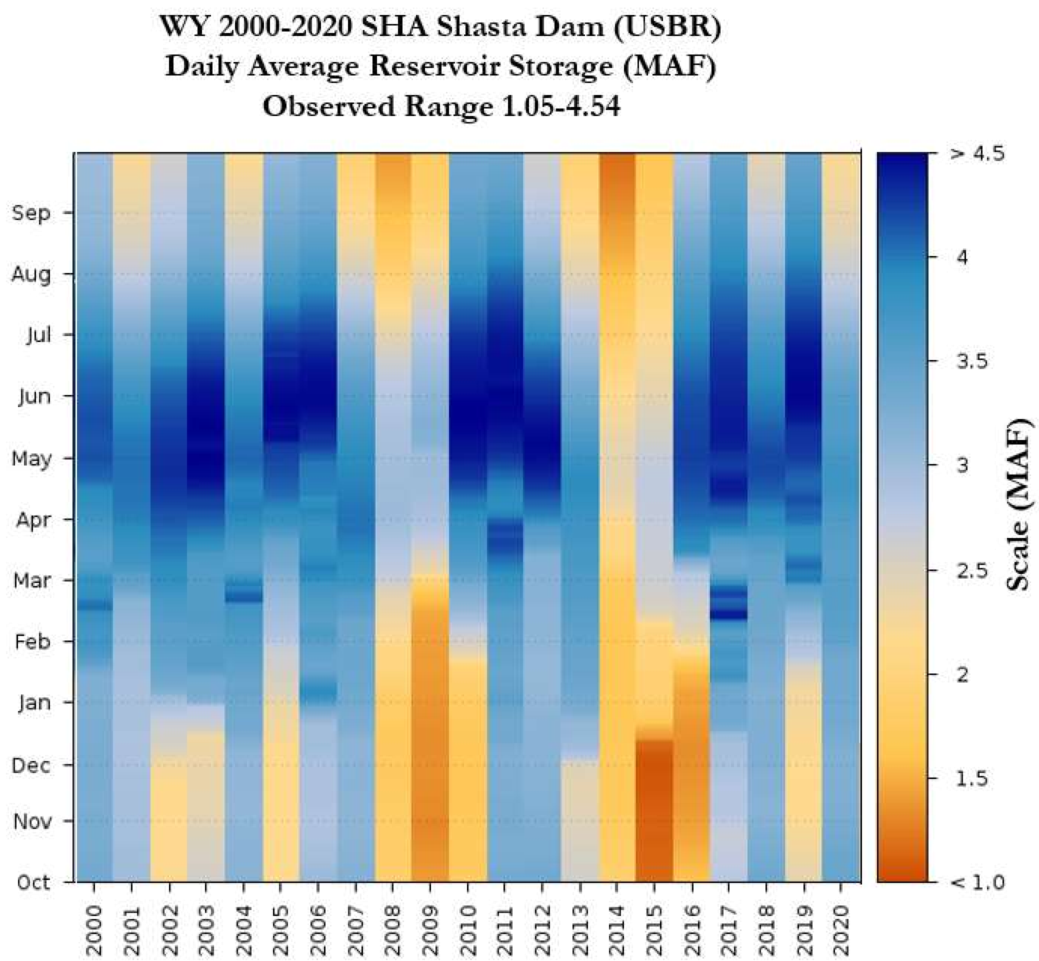

Figure 3. Daily average Shasta Lake storage from WY 1995 2000 - 2020. Source: http://www.cbr.washington.edu/sacramento/data/query_river_allyears.html

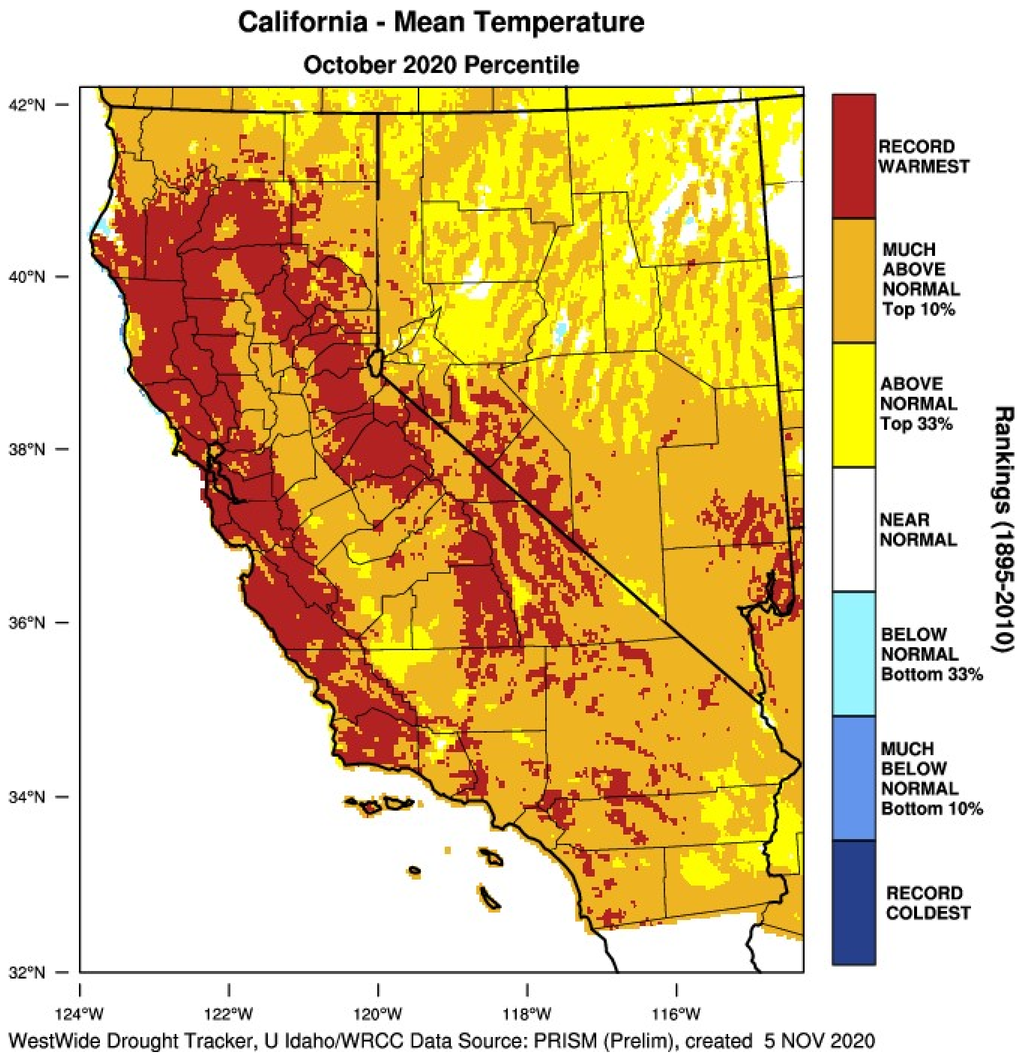

Figure 4. Mean Monthly Temperature Ranking of October 2020 for a period of record (1895 - 2010).

General Water Year Conditions and Operations

WY 2020 yielded below average rainfall and snow during the late winter and spring months. In general, storage conditions in reservoirs were high in the fall of 2019 as a result of plentiful hydrologic conditions the previous year. Despite a strong start at the beginning of the water year with over 13 inches of precipitation recorded at Shasta Dam in the month of December, the remaining months were particularly dry.

In December storage conditions were above the highest elevations allowed by the U.S. Army Corps of Engineers (USACE). As a result, Keswick Dam releases were increased to make flood space for flood control purposes to maintain an acceptable flood risk. February is typically one of the most productive runoff months at Shasta Dam, however, in WY 2020 gauges measured zero precipitation and inflows to Shasta Lake declined. Rain gauges reported a total of 34.5 inches for the water year, a

startling difference between the prior wet year's 89.3 inches for the water year. Precipitation in March and particularly May recovered moisture in the system but fell short to make up for the lack of storm events in February. Snowpack for the northern state was poor, reaching slightly above 50% of the average of the April 1 snow water equivalent. The Sacramento Eight Station Index for WY 2020 reported 31.74 inches of precipitation for the region. Water supply indices reported the Sacramento River Unimpaired Runoff was a "Dry" year for the Sacramento Valley Index (DWR 2020). Unusually warm air temperature conditions were also noted this year as well as prolonged smoke and haze as a result of large, widespread, and persistent regional fires. Highly variable warming and cooling trends again challenged water temperature management.

Operational decisions on the upper Sacramento River are influenced by local and CVP and SWP system-wide multi-purpose objectives, including those that are planned and uncertain. Many factors contribute to operational actions including, but not limited to forecasted inflows, facility maintenance schedules, physical/mechanical facility limitations, upstream operations, minimum in-stream flow criteria, downstream Delta regulatory requirements, Delta exports, power generation, recreation, fish hatchery accommodations, water temperature management capabilities, and others. In addition, uncertain or unplanned events can also influence real-time operation decisions (e.g. wildfire events, or reservoir release reductions for USACE downstream flood protection). Planned operational targets are regularly updated late winter through early summer depending on hydrologic conditions on Reclamation's website (https://www.usbr.gov/mp/cvo/).

Hydrologic Conditions

Watershed runoff in the upper Sacramento River basin is typically dominated by cold winter precipitation that refills and replenishes both Shasta Lake's total storage and the cold water pool. The runoff is quantified as late spring through summer (April through July) inflow volume. The Sacramento River watershed basin runoff forecasted inflow volume and its quality (i.e. water temperature) is fundamental to operational planning. The inflow volume projection is updated routinely by DWR and the National Weather Service-California Nevada River Forecast Center (CNRFC), where uncertainty is represented by percent runoff exceedances (Figure 5). By May, water supply forecasts for Shasta Lake inflow runoff ranged between 51% and 56% of the average for the 90% and 50% runoff exceedances, respectively (DWR 2020). The actual full natural flow of Shasta Lake inflow volume April through July was 1.10 MAF and the final water year volume was 3.30 MAF (DWR 2020b).

Table 1 provides insight to the hydrologic characteristics of WY 2020. Because operational planning is significantly influenced by future forecasts, these uncertainties and modified decisions are translated into the performance and efficiency of the system-wide operation.

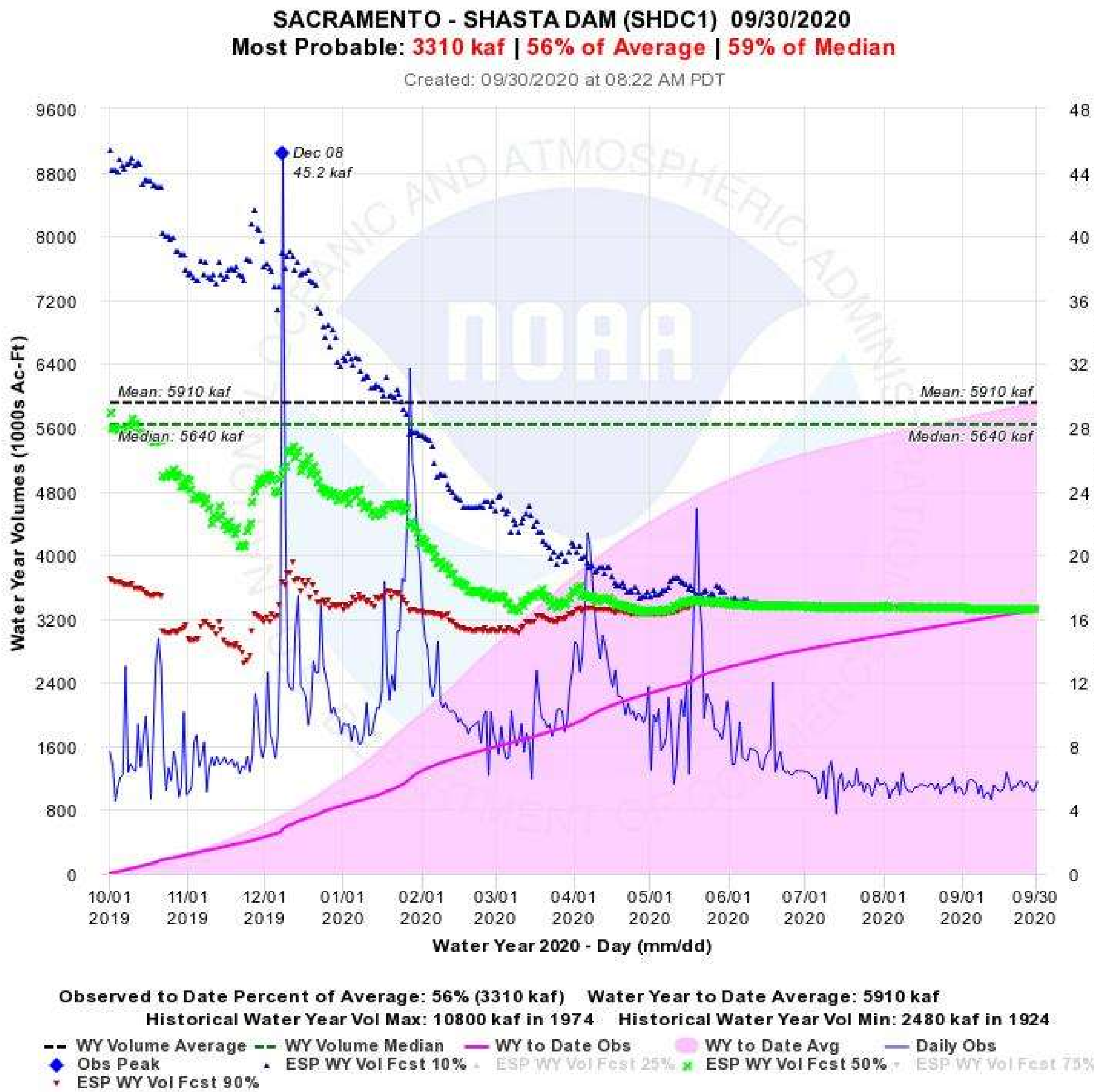

Figure 5. WY 2020 forecasted (10%, 50%, 90% exceedance) and actual daily and cumulative inflow volume at Shasta Lake. Source: https://www.cnrfc.noaa.gov/water_resources_update.php

Table 1. WY 2020 Northern Sierra precipitation, Sacramento Basin snowpack, and Sacramento Valley Index statistics by month.

Water Year 2020 Month	Northern Sierra 8-Station Precipitation (Cumulative water year in inches through month)	Northern Sierra 8-Station percentage of historic monthly average precipitation (for month)	Sacramento River Basin Snowpack (percent of April 1st average)	Sacramento Valley Index (40-30-30 Index 50% Exceedance)
November	2.3	30%	NA	NA
December	13.0	116%	NA	7.3
January	17.8	54%	34	7.6
February	17.8	0%	48	6.7
March	24.0	83%	39	5.9
April	26.8	74%	58	6.0
May	31.1	195%	29	6.0

Key Events/Decisions

The key events and decisions that influenced the 2020 upper Sacramento River Temperature operations include:

- Fall Keswick Release Pulsing: SRTTG members and SRSC coordinated a pilot operation (fall 2019) to manage downstream delivery demand and fishery protection. By coordinating delivery of water required for rice decomposition in the fall, managers discouraged fall-run Chinook salmon from spawning at higher flow rates, thus reducing the potential to dewater redds once the water demand for rice decomposition has been met. This pilot operation was an attempt to meet multi-objective purposes in the system while continuing to minimize fishery impacts. Releases were pulsed from Keswick Dam to afford a larger volume of water for diversion downstream.
- Flood Risk and USACE Flood Control Space Operations: Winter flood risk was elevated due to high Shasta Lake storage conditions in October 2019 through early January 2020. This influences Keswick Dam's winter base flow release of 5,000 cfs to maintain the USACE flood control reservation for the winter season. Flood control reservation was maintained in December 2019

which resulted in higher releases from Keswick Dam during this period at 7,000 cfs. Per USACE criteria, no additional Shasta Lake storage could be retained at the end of December.

- Operational Guidance: The ROD was signed on February 18, 2020. Prior to the signing of the ROD, the 2008/2009 USFWS and NMFS Biological Opinions were guiding operations.
- Storms: While there was refill potential in Shasta Lake afforded by the USACE flood control curve, January through March 2020 yielded few storm events offering little chance for Shasta Lake refill.
- Shasta Storage: By late March 2020, prior to agricultural demands/diversions, total Shasta Lake storage volume did not recover and refill as a result of dry hydrology and low inflow volumes. In addition, end of water year Shasta Lake storage condition was projected to be poor. End of water year Shasta Lake storage totaled 2.2 MAF, slightly greater than the average dry year storage of 2.1 MAF (see Figure 8 in the Storage and Flood Conservation Space section for dry year storage performance and averages).
- Trinity River Diversion: Early spring forecasts suggested dry hydrologic conditions and low Shasta Lake elevations, which would make it difficult to maintain access to the TCD Upper Gates. In response to these forecasts, Trinity River Diversions were significantly increased for the entire season. This increase allowed water to remain in Shasta Lake while Trinity River water was used to augment Sacramento River flows and improve future Sacramento River temperature performance.
- Spring Keswick Dam Release: Releases were reduced in the spring multiple times for storage conservation to rebuild Shasta Lake storage and the cold water pool, and to reach an elevation to access the TCD Upper Gates. More plentiful January storm events and runoff established Delta requirements for the month of February. These requirements affected Keswick Dam releases as February was unusually dry increasing the need for storage withdrawals to support Delta requirements in February and March. Keswick Dam releases increased in early April in response to increasing agricultural demands (see Figure 9 in the Storage and Flood Conservation Space section for dry year releases from Keswick Dam and averages).
- TCD Upper Gates: Forecasts as late as April suggested no or minimal use of the TCD Upper Gates. Access to the TCD Upper Gates minimizes early use of the cold water pool and can extend the success of water temperature control for the cold water pool management season through the fall. A coordinated effort among SRTTG members and SRSC to reduce Keswick Dam releases and capture storage gains for the last significant storm event of the season, which occurred in mid-April, was successful. Shasta Lake storage improved and the Upper TCD Gates were used through the end of June.
- Spring Pulse Determination: Per the Spring Pulse Flow criteria adopted in the ROD, since the projected and actual May 1 storage of Shasta Lake was less than 4 MAF (indicating insufficient cold water pool for Tier 1), a Spring Pulse flow was not pursued in order to protect the cold water pool and water temperature management performance for the 2020 season.
- Shasta Critical Year Determination: In February, a Shasta Critical Year was announced (in part, based on projected Shasta Lake Inflow) which reduces the SRSC to 75% delivery allocation.

However, this determination was later reversed on June 8, 2020 as a result of improved hydrologic conditions. Although this late season Shasta Critical Year allocation adjustment is unusual, this minimally influenced the CVP Operational Outlooks, release and storage projections used in the development of the 2020 Sacramento River Temperature Management Plan.

- Below Average Cold Water Pool Development at the Coldest Volumes: Water year 2020 cold water pool observations suggested below average development at the coldest volume, less than 48°F (see Figure 10 in the Storage and Flood Conservation Space section for cold water pool development less than 48°F in WY2020 and averages). This influenced the 2020 Sacramento River Temperature Management Plan and conservative decision making for the season. Historical conditions of the CWP and water temperature performance are recorded in Table 2 and Table 3 for comparison.
- 2020 Temperature Management Plan (TMP): Preliminary evaluation of likely Tiers began in February. In March, tools were developed to evaluate whether WY 2020 could fall into a Tier 2 and Tier 3. A Tier 3 draft TMP was distributed in April, and a final Tier 3 TMP in May.
- Summer Meteorological Conditions: Widespread wildfire activity throughout the summer impacted local meteorological conditions including solar radiation and thermal influences.
- TCD Gates and Curtain Deployment: Deployment of the Middle Gate curtain prevented warm water leakage into the TCD, affording more confident temperatures downstream.

Table 2. Historical Shasta Lake Storage Volumes and Cold Water Pool Volumes in Thousands of Acre Feet (TAF).

Shasta Lake Historical Storage Conditions 2010-2020								
Water Year	**Peak Storage**		**End of April Volume < 56°F**	**Date 1st Side Gate Opened**	**End of September Volume**			
	Volume	**Date**			**Storage**	**< 56°F**	**< 52°F**	**< 50°F**
2010	4507	05/22	3771	09/17	3319	1216	744	516
2011	4492	06/02	3809	N/A	3341	1340	903	707
2012	4483	05/07	3791	09/21	2592	765	598	512
2013	3887	04/18	2809	09/11	1906	425	347	309
2014	2409	04/28	1770	08/07	1157	107	81	63
2015	2722	04/15	1912	09/13	1603	358	270	228
2016	4235	05/01	3267	10/23	2811	938	730	596
2017	4389	05/13	3975	N/A	3382	1146	806	594
2018	4200	04/26	3135	09/19	2405	607	485	388
2019	4477	05/31	3441	N/A	3425	1203	907	707
2020	3750	04/21	2986	08/13	2200	476	344	230

Table 3. Historical Sacramento River Temperature Compliance Point Data

Sacramento River Historic Temperature Control Point 2010-2020 Daily Average Temperature - Degrees Fahrenheit (Days Applied)									
Year	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
2010	BSF-56°	BSF-56° (01-14) JLF-56° (15-30)	JLF-56° (01-10) BSF-56° (11-24) JLF-56° (25-31)	JLF-56°	JLF-56°	JLF-56°	JLF-56°	JLF-56°	JLF-56°
2011	BSF-56°	BSF-56°	BSF-56°	JLF-56°	JLF-56°	JLF-56°	JLF-56°	JLF-56°	JLF-56°
2012	JLF-56°	JLF-56° (01-15) BSF-56° (16-30)	BSF-56°	JLF-56°	JLF-56°	JLF-56°	JLF-56°	BSF-56°	BSF-56°
2013	BSF-56°	BSF-56°	BSF-56° (01-16) [1]BSF-**56.75°** (17-31)	[1]BSF-**56.75°**	[1]BSF-**56.75°**	[1]BSF-**56.75°**	[1]BSF-**56.75°**	[1]BSF-**56.75°**	[1]BSF-**56.75°**
2014	BSF-56° (01-27) CCR-**58°** (28-31)	CCR-**58°** (01-24) CCR-56° (25-30)	CCR-56°	CCR-56°	CCR-56°	CCR-56°	CCR-56°	CCR-56°	CCR-56°
2015[2]	CCR-56°	CCR-56° (01-17) CCR-**58°** (18-30)	CCR-**58°** (01-14) CCR-56° (15-31)	CCR-56° (01-04) CCR-**58°** (05-30)	CCR-**58°**	CCR-**58°**	CCR-**58°**	CCR-**58°**	CCR-**58°**
2016	CCR-**58°**	CCR-**58°**	CCR-**58°**	CCR-**58°** (01-16) BSF-56° (17-30)	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°
2017[3]	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°
2018[4]	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°
2019[5]	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°	BSF-56°
2020[6]	BSF-56°	BSF-56°	BSF-56° *CCR - 54.5° (15-30) CCR - 53.5° (31)*	BSF-56° *CCR - 53.5° (1-29) CCR - 54° (30)*	BSF-56° *CCR - 54°*	BSF-56° *CCR - 54°*	BSF-56° (01-20) CCR-56° (21-30)	CCR-56°	CCR-56°

[1] BSF-56.75°F used as surrogate for Airport Road 56°F
[2] Year 2015 July – November the temperature target was 57°F, not to exceed 58°F
[3] Year 2017 pilot evaluation study also targeted CCR at 53°F May 15 – Oct 31
[4] Year 2018 pilot evaluation study also targeted CCR at 53.5°F May 15 – Oct 31
[5] Year 2109 pilot evaluation study also targeted CCR at 53.5°F May 15 – Oct 31 and Airport Road at 53.5°F Aug 7 – Oct 31

[6]Year 2020 Temperature Management plan specified a target of 56°F at locations BSF and CCR per SWRCB WR90-5 requirements, targets at CCR are also listed as specified in the Temperature Management Plan

BSF = Balls Ferry, JLF = Jelly's Ferry, CCR = Sacramento River upstream of Clear Creek confluence

Storage and Flood Conservation Space

Actions taken in the late fall and early winter of WY 2020 prior to the signing of the ROD on February 18, 2020 also influenced the storage conditions of Shasta Lake. Shasta Lake storage was controlled by USACE flood reservation space requirements late fall and early winter (Figure 6 and Figure 7). No additional water could be stored in Shasta Lake as a result of these requirements in December 2019. Due to dry hydrology following December 2019, Shasta storage conditions did not refill, end of April storage was 3.687 MAF. Compared to other dry water years (2000 – 2020), WY 2020 had higher storage volumes until mid-January (Figure 8). Further, compared to the average dry water year (2000-2020), Keswick Dam releases were greater in the winter of WY 2020 (Figure 9). WY 2020 cold water pool observations suggested below average development at the coldest volume, less than 48°F (Figure 10). This influenced of the 2020 Sacramento River Temperature Management Plan and conservative decision making for the season. Historical conditions of the cold water pool are recorded in Table 2.

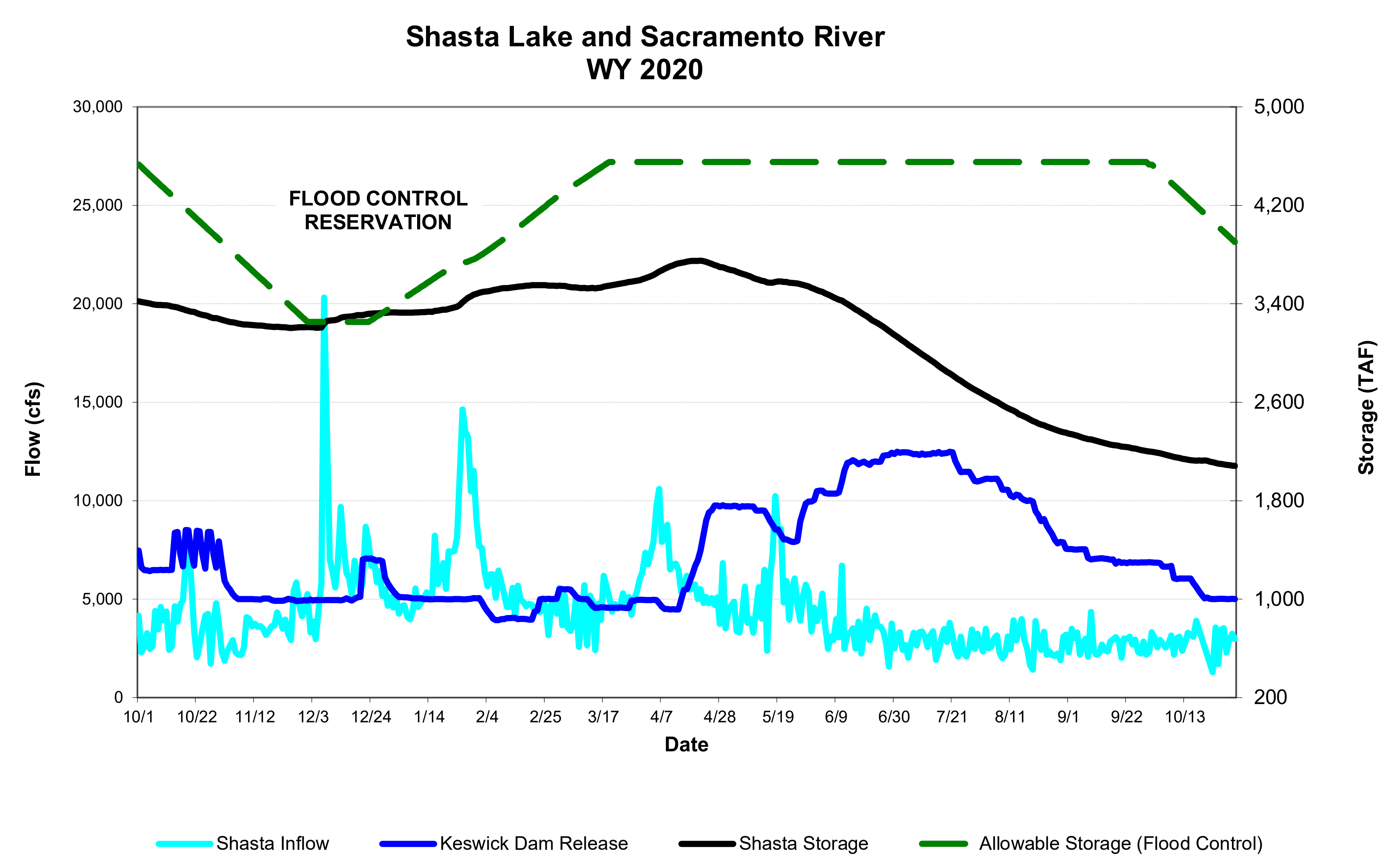

Figure 6. Shasta Lake Storage (black line), Allowable Storage for Flood Control (green line), Keswick Dam Release (dark blue line), and Shasta Inflow (light blue line) for 10/1/2019 - 10/31/2020.

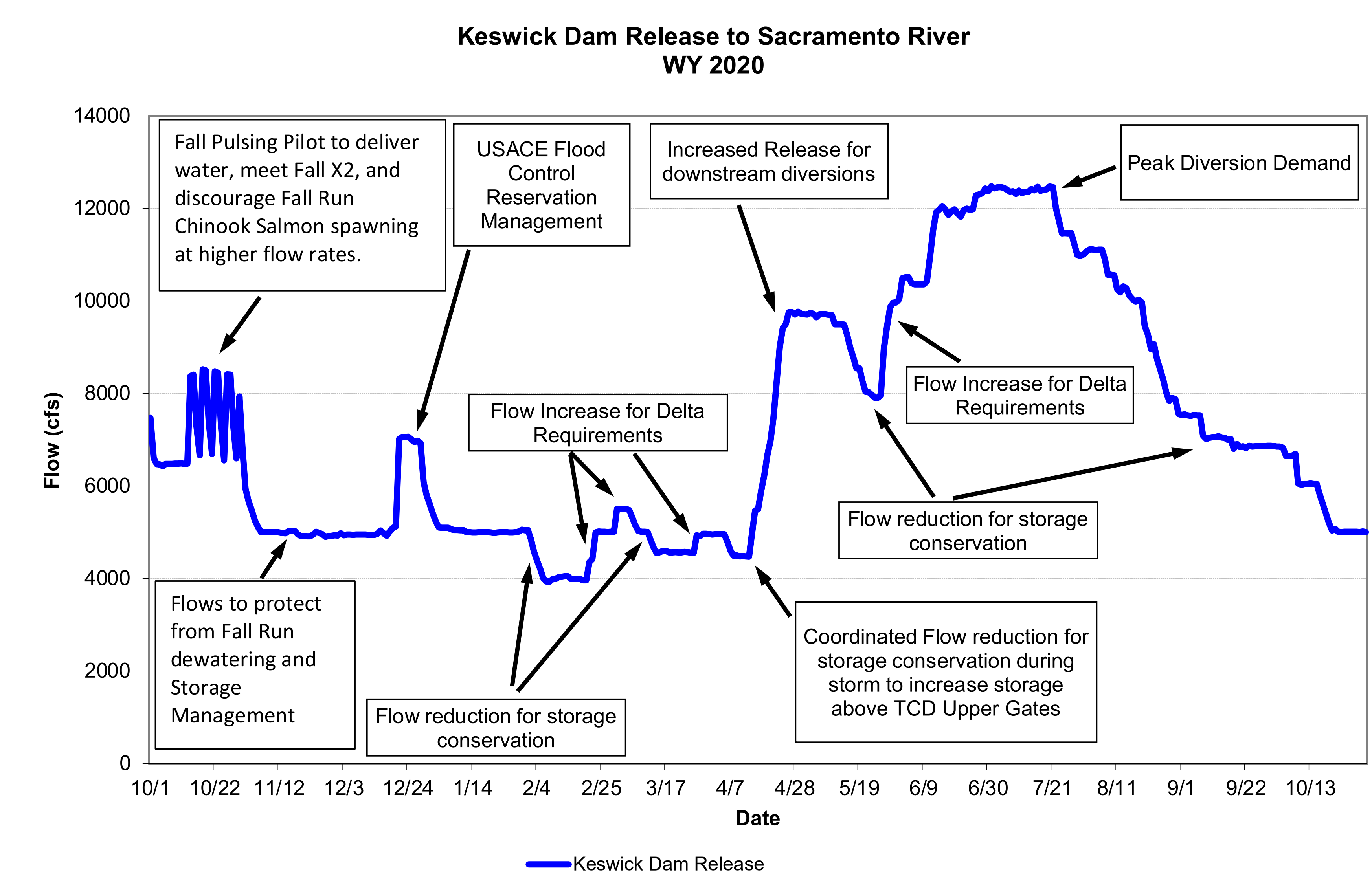

Figure 7. Sacramento River Releases from 10/1/2019 - 10/31/2020 with major events highlighted

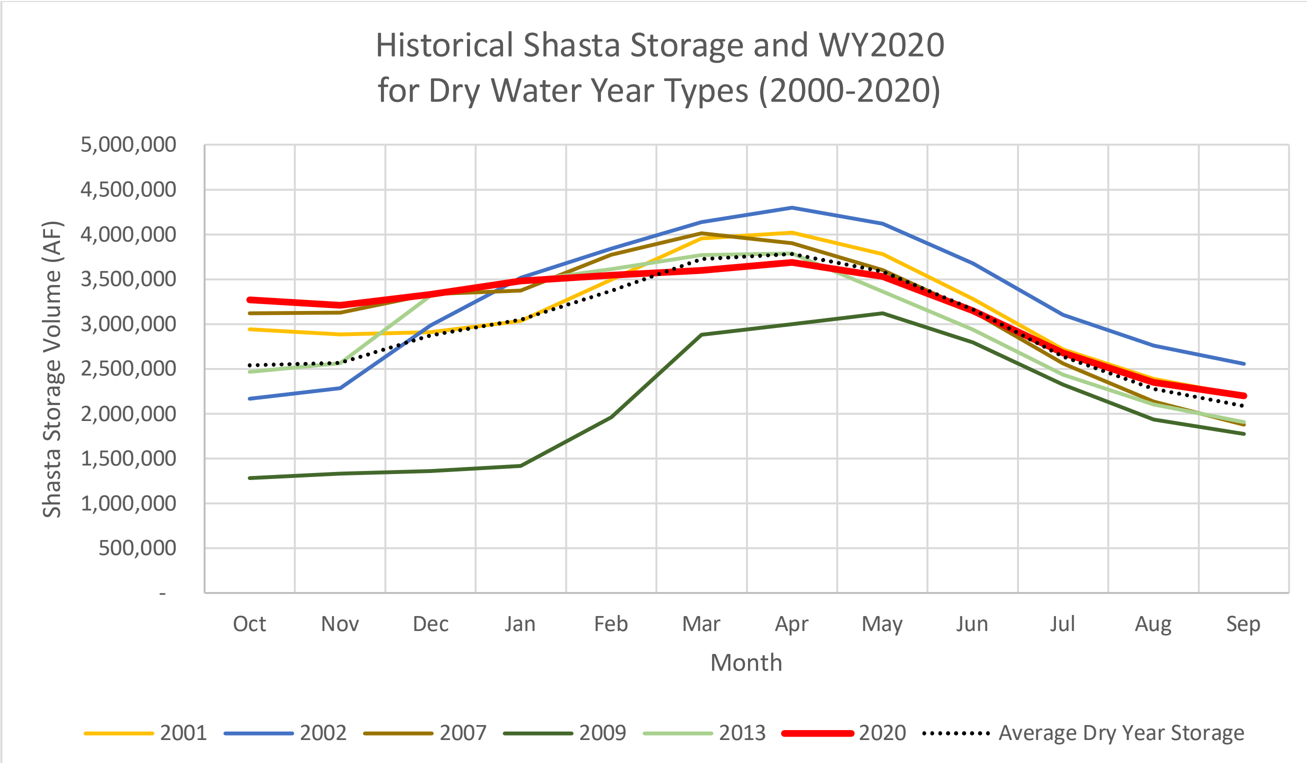

Figure 8. Historical Shasta Storage and WY2020 for Dry Water Year Types (2000- 2020).

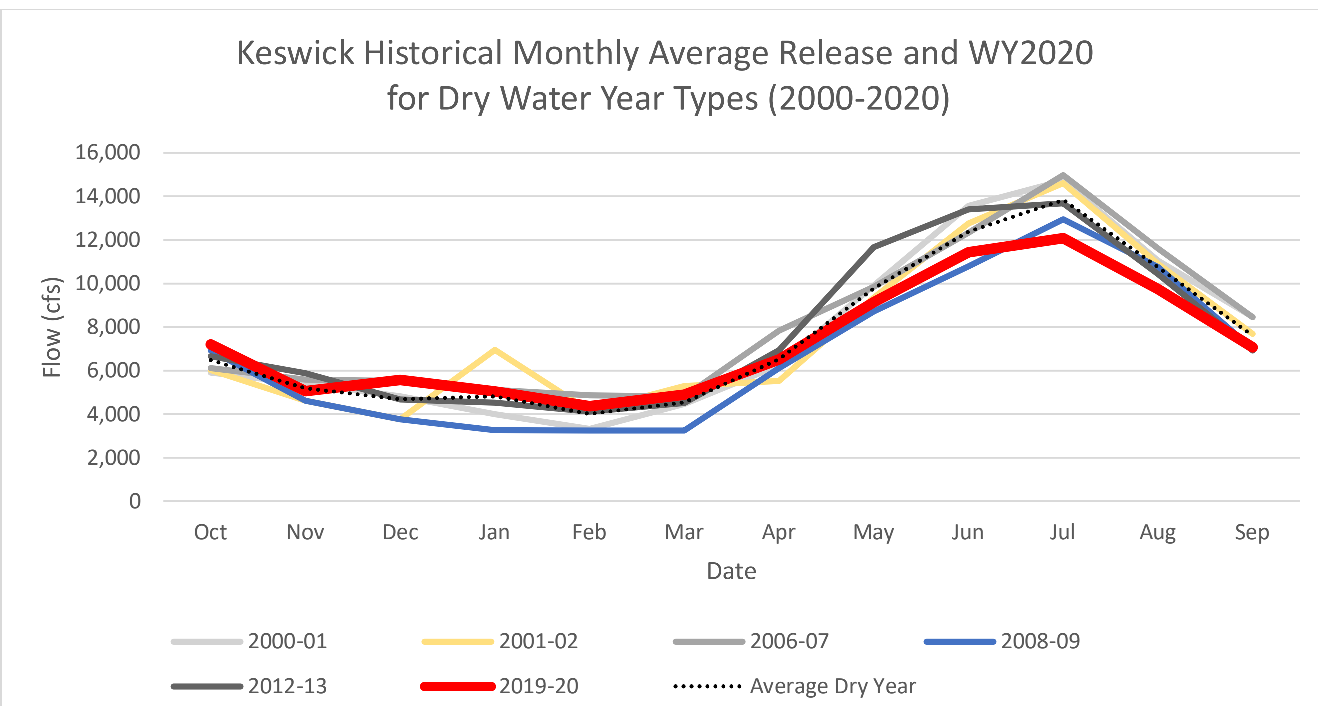

Figure 9. Keswick Historical Monthly Average Releases and WY2020 for Dry Water Year Types (2000-2020).

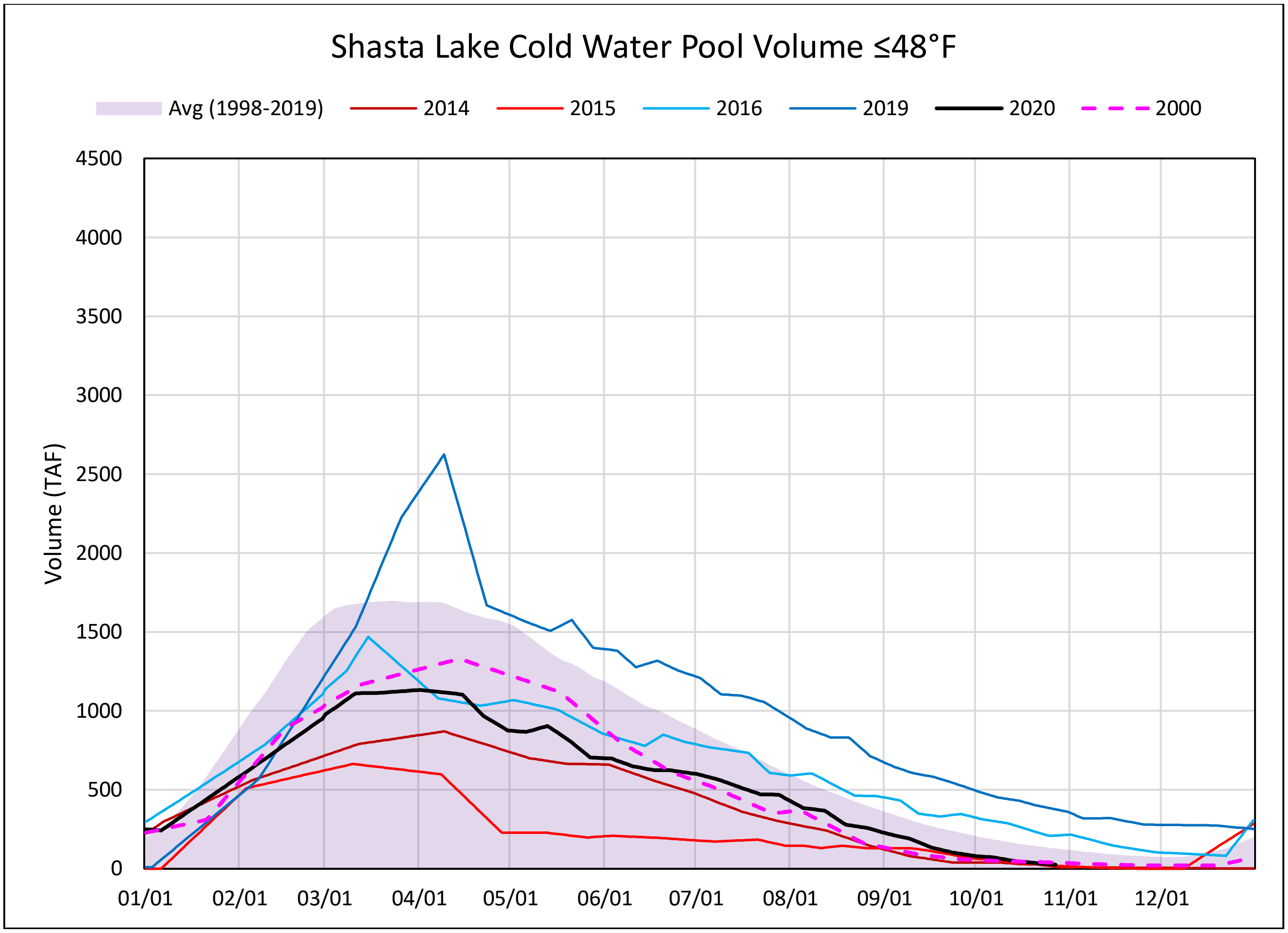

Figure 10. Shasta Lake cold water pool volume less than 48°F.

Fall and Winter Refill

Actions taken in the late fall and early winter of WY 2020 prior to the signing of the ROD on February 18, 2020 also influenced the storage conditions of Shasta Lake. Fall flow reduction schedule discussions with the fish agencies (NMFS, CDFW, and USFWS) and Reclamation began in September 2019. Meetings took into consideration the needs of fish, Shasta Lake storage, and downstream water needs (rice decomposition, Wilkins Slough, waterfowl habitat, Delta water quality). Various flow reduction scenarios were developed with considerations and recommendations for fisheries to: (1) avoid or minimize dewatering of winter-run Chinook salmon redds; (2) reduce Keswick Dam releases quickly in order to minimize the potential for fall-run Chinook salmon redd dewatering; (3) stabilize Keswick Dam releases through approximately January 2020 to continue to minimize the potential for fall-run Chinook salmon redd dewatering; and (4) maintain base flows of 5,000 cfs or greater to preserve juvenile winter-run Chinook salmon rearing habitat and decrease juvenile stranding.

SRTTG members and SRSC coordinated a pilot operation in fall 2019 to manage downstream delivery demand and fishery protection (Figure 7). In 2019, managers discouraged fall-run Chinook salmon from spawning at higher flow rates by releasing short flow pulses during the delivery period,

thus reducing the potential for fall-run Chinook to build redds in areas intermittently watered by the higher flow peaks. When releases to meet diversion demand for rice decomposition had been met, flows remained at the base release for the remainder of fall-run Chinook salmon egg incubation period. This operation was an attempt to meet multi-objective purposes in the system while continuing to minimize fishery impacts.

Spring Pulses

Releases from Keswick Dam were reduced in the spring multiple times for storage conservation to rebuild Shasta Lake storage and the cold water pool, and to reach an elevation to access the TCD Upper Gates (Figure 7). More plentiful January storm events and runoff established Delta requirements for the month of February. These requirements resulted in increased Keswick Dam releases as February was unusually dry, increasing the need for storage withdrawals to support Delta requirements in February and March. Keswick Dam releases also increased in early April in response to increasing agricultural demands (Figure 7).

At the April 23, 2020 SRTTG meeting, representatives from the Sacramento River Spring Pulse Team presented a proposal for a spring pulse flow and the group discussed pulse study alternatives and tradeoffs. Although projected Shasta Lake storage for May did not meet the initial criteria for a spring pulse (e.g. projected May 1 storage was less than 4 MAF indicating insufficient cold water pool for Tier 1), the proposal was still discussed as the 2020 ROD allows for coordination with the Upper Sacramento Scheduling Team to consider a pulse when the reservoir is less than 4 MAF, and the pulse would not interfere with the ability to meet performance objectives or other anticipated operations of the reservoir. Future TMPs will routinely include a spring pulse flow analysis as specified in guidance documentation. During the Water Operation Management Team (WOMT) discussion on May 6, 2020, members recommended no spring pulse flow for 2020 due to Sacramento River water temperature risk concerns (WOMT notes can be found at https://usbr.gov/mp/bdo/water-operations-management.html). Reclamation did not include a spring pulse in the 2020 TMP.

Under the ROD, Reclamation may release spring pulse flows of up to 150 TAF in coordination with the Upper Sacramento Scheduling Team when the projected total May 1 Shasta Lake storage indicates a likelihood of sufficient cold water to support summer cold water pool management, and the pulse does not interfere with the ability to meet performance objectives or other anticipated operations of the reservoir. Reclamation may implement a spring pulse flow under certain hydrologic conditions to improve the survival of out-migrating juvenile salmonids, specifically Central Valley spring-run Chinook salmon.

Summer/Fall Water Temperature Management

The following section describes conditions and actions taken to manage the risk associated with summer and fall water temperature management. Water temperature management is implemented within the context of future uncertain conditions and limited resource availability. To address uncertainty, conservative estimates of future conditions are used in the modeling assumptions (e.g. hydrology, operations, and meteorology) and projections are updated regularly through the

management period. A tiered strategy is applied in limited cold water pool years to strategically apply temperature objectives. Risk management incorporates these components aims to achieve the goal of minimizing undesirable temperature effects for the entire season.

February

Storage conditions and trending hydrology in the late winter months can offer some insight on the trajectory of the cold water pool management but should be interpreted cautiously due to variable hydrology during this time. The most productive months for storms, runoff and inflow to Shasta Lake are in the late winter and spring. Keswick Dam releases are traditionally at their lowest point of the year in this period, supporting minimum flows, Delta exports, and Delta requirements. Although counterintuitive, drier hydrologic years can require higher than normal releases from storage to support downstream Delta requirements in the late winter and early spring, prior to increased releases for agricultural diversion beginning in mid-April. Additional releases can undermine goals to increase storage, however, hydrology is generally the most significant parameter that drives reservoir refill and cold water pool replenishment in the late fall through spring period. In February 2020, Shasta Lake storage recovery was low, inflow performance was unusually low due to unusually dry conditions and forecasts suggested dry hydrological trends. Releases from Keswick Dam were used to maintain flows to protect dewatering fall-run Chinook salmon redds, increasing storage in Shasta Lake per USACE Flood Control Reservation Management, and delta requirements (Figure 7). Keswick Dam releases were reduced for storage conservation in February. Coincident in the same period, releases were increased for Delta requirements (SWRCB D-1641 requirements with outflow targeting 11,400 cfs for the entire month). Very dry hydrology in February 2020, as flood storage reservation relaxed, resulted in low Shasta Lake storage conditions at the end of the month.
To examine future in-stream temperature performance in February, two forms of insight to future cold water pool management were assessed: (1) Relationship between total Shasta Lake storage/cold water pool and potential future temperature compliance; and (2) preliminary water temperature model simulation results. Water temperature performance for the year was estimated to be approximately between 54°F-56°F at Clear Creek River gage (CCR) based on projected May 1 total Shasta Dam storage and projected cold water pool conditions. Preliminary water temperature simulations were characterized as runs ruling out particular Tiers and did not necessarily depict operations. At this time, use of the Upper TCD gates was limited due to existing and projected Shasta Dam storage conditions. Modeling results suggested that attempting to meet a Tier 1 condition (maintaining 53.5°F at CCR for the entirety of the temperature management season) was infeasible as the projected end of September cold water pool volumes indicated a loss of temperature management control in the fall. Additional modeling suggested that a lower tier than Tier 4 was feasible; results found maintaining 56°F at CCR for the water temperature management season was achievable with a projected end of September cold water pool volume sufficient to sustain the fall cold water pool target. By process of elimination, Tier 2 and Tier 3 were viable possibilities.

March

March is typically a storage and cold water pool building month. However, in March 2020, Shasta Lake storage recovery gained only approximately 52 TAF for the month; Delta conditions experienced the lag of February's lack of precipitation. Keswick Dam releases were again reduced

for storage conservation but were countered by flow increases for Delta salinity requirements. In March 2020, low seasonal storage was expected as significant precipitation opportunities dwindled and use of the TCD Upper Gates was assumed unachievable due to existing and projected Shasta Lake storage conditions. All Upper and Middle TCD gates were open due to elevation restrictions for the TCD.

Shasta Critical Year type designation occurs at this time, and this year determination was too close to the threshold to determine with certainty the type of year. Based on guidance, no plans to initiate intervention discussions were needed as the March 90% runoff exceedance forecast suggested a May 1 storage condition of greater than 2.5 MAF. Two forms of insight to future cold water pool management were again assessed: (1) Relationship between total Shasta Lake storage/cold water pool and potential future water temperature compliance; and (2) preliminary water temperature model simulation results. Water temperature performance for the year was estimated to be higher than approximately 54°F-56°F at CCR based on projected May 1 total Shasta Lake storage and projected cold water pool conditions. Similarly, modeling runs were performed to rule out particular Tiers and did not necessarily depict operations. Modeling results suggested that attempting to meet a Tier 1 condition (i.e. maintaining 53.5°F at CCR for the temperature management season) was infeasible, as the projected end of September cold water pool volumes indicated a loss of water temperature management control in the fall. Additional modeling suggested that a Tier 4 was feasible; results found maintaining 56°F at CCR for the water temperature management season was achievable, but the projected end of September cold water pool volume was insufficient to sustain the fall target.

In conjunction with SRTTG members input, activities in March highlighted the development of the Temperature Tier Selection Protocol (TTSP). The TTSP is designed to serve SRTTG as a tool in defining the Tier 2 and Tier 3 alternatives (specifically the timing and magnitude of the temperature target). As a result of the flexibility offered in Tier 2 and Tier 3, a structured approach (borrowing similar logic of the American River process to inform water temperature management) was established to evaluate limited cold water pool conditions and prioritize in-river cooling timing scenarios to maximize winter-run Chinook salmon benefit. Key features of the TTSP include:

- Bound exploration of scenarios between Tier 1 and Tier 4, and
- Incrementally explore Shasta Lake tail-bay temperature target scenarios by evaluating:
    - Down-stream temperature predicted performance,
    - End of September predicted cold water pool volume,
    - Estimated use of the TCD Side Gates, and
    - Estimated Life Stage-dependent and Life Stage Independent: Temperature Dependent Mortality

Goals include selecting a scenario that minimizes water temperature dependent mortality, presents a feasible TCD operation, and minimizes the risk of degrading expected performance of the selected Tier (i.e. shifting to a warmer Tier). Preliminary definitions of Tier 2 and Tier 3 were formulated; however, they are not finalized. Recommendations for the future include refinements, when additional biological information becomes available.

April

In early April a moderate sized storm event opportunity was seized, supported by cooperation from SRTTG members and SRSC, and resulted in (albeit minor) release reductions and significant (just enough) storage gains to reach utilization of the TCD Upper Gates. This event proved to be a pivotal turning point in the success of the Sacramento River temperature management for the 2020 season. Despite improved storage, cold water pool volumes were closely monitored as the coldest volume (less than or equal to 48°F) showed diminished volumes in comparison to past years (e.g. as shown in Figure 10, in April 2020, cold water pool volume less than or equal to 48°F is approximately half of the average volume, tracking close to 2016). Due to continued uncertainty and the indices proximity to thresholds, a Shasta Lake Critical year determination was announced as likely, but not finalized. Spring Pulse flows were also considered despite guidance that suggested Shasta Lake storage conditions were insufficient; challenges included degradation to the cold water pool impacting seasonal temperature performance and potential ACID dam facility issues due to Keswick Dam releases at or in excess of 15,000 cfs. Based on guidance, no plans to initiate intervention discussions were needed as the April 90% runoff exceedance forecast suggested a May 1 storage condition of greater than 2.5 MAF.

As with previous month's evaluations, two forms of insight to future cold water pool management were again assessed: (1) Relationship between total Shasta Lake storage/cold water pool and potential future water temperature compliance; and (2) preliminary water temperature model simulation results now considered in association with the TTSP process. Temperature performance for the year was improved with April storage gains, and estimated to be approximately 54°F-56°F at CCR based on projected May 1 total Shasta Lake storage and projected cold water pool conditions. Modeling runs were performed via TTSP to explore within Tier performance. Modeling results (with various scenarios) suggested a Tier 3 condition, maintaining 53.5°F at CCR for a portion of the season, was feasible and projected end of September cold water pool volumes indicated maintained water temperature management control in the fall with reasonable timing of TCD Side Gate use. Considerable discussion covered the topics of timing of the TCD Side Gate use, uncertainty of the meteorology, limitations of the water temperature model predictions in the fall, and confidence in the end of September cold water pool/fall temperature performance relationship. Conservative planning for operational targets were also discussed:

- Prioritize cold water pool resources, ideally to 53.5°F, during the winter-run Chinook salmon critical time frame (period centered on or about August 8, 2020)
- Target minimum end of September cold water pool volume less than 56°F (based on end of September cold water pool and downstream temperature performance relationships) to maintain 56°F at CCR from mid-September through the end of October: 460 TAF
- Delay the date of the first TCD Side Gate use: Approximate historical use for confidence in maintaining fall temperature control - August 20, 2020
- Minimize winter-run Chinook salmon estimated water temperature dependent mortality

Technical assistance from SRTTG members was used to evaluate feasible scenarios. The proposal, by construction, subjected additional performance risk by utilizing cold water pool earlier in the season when conditions are still uncertain, rather than taking on additional risk later in the season when conditions are more certain. A draft Sacramento River Temperature Management Plan was

circulated to SRTTG membership for comment. The Temperature Management Plan proposed a Tier 3 performance expectation given a volume of cold water pool/Side Gate use to support a target of between 53.5°F and 56°F during the critical egg incubation period at CCR.

May

May initiates the end of typical significant precipitation/runoff, and begins climatic warming and the initial inspection of actual stratified cold water pool volume in Shasta Lake (Figure 11). A Shasta Critical Year determination was again delayed due to continued uncertainty and indices proximity to the threshold. In May a decision was made to prioritize Tier 3 temperature performance above a spring pulse flow; no additional releases were planned for the spring pulse flow due to water temperature management concerns. Based on guidance from the 2020 ROD, no plans to initiate intervention discussions were needed as the May 1 storage condition was greater than 2.5 MAF, and cold water pool conditions were less than 2.8 MAF; guidance suggested a Tier 2 condition (this discrepancy is due in part to both modeling performance and further definition of Tier 2 and 3 as previously mentioned).

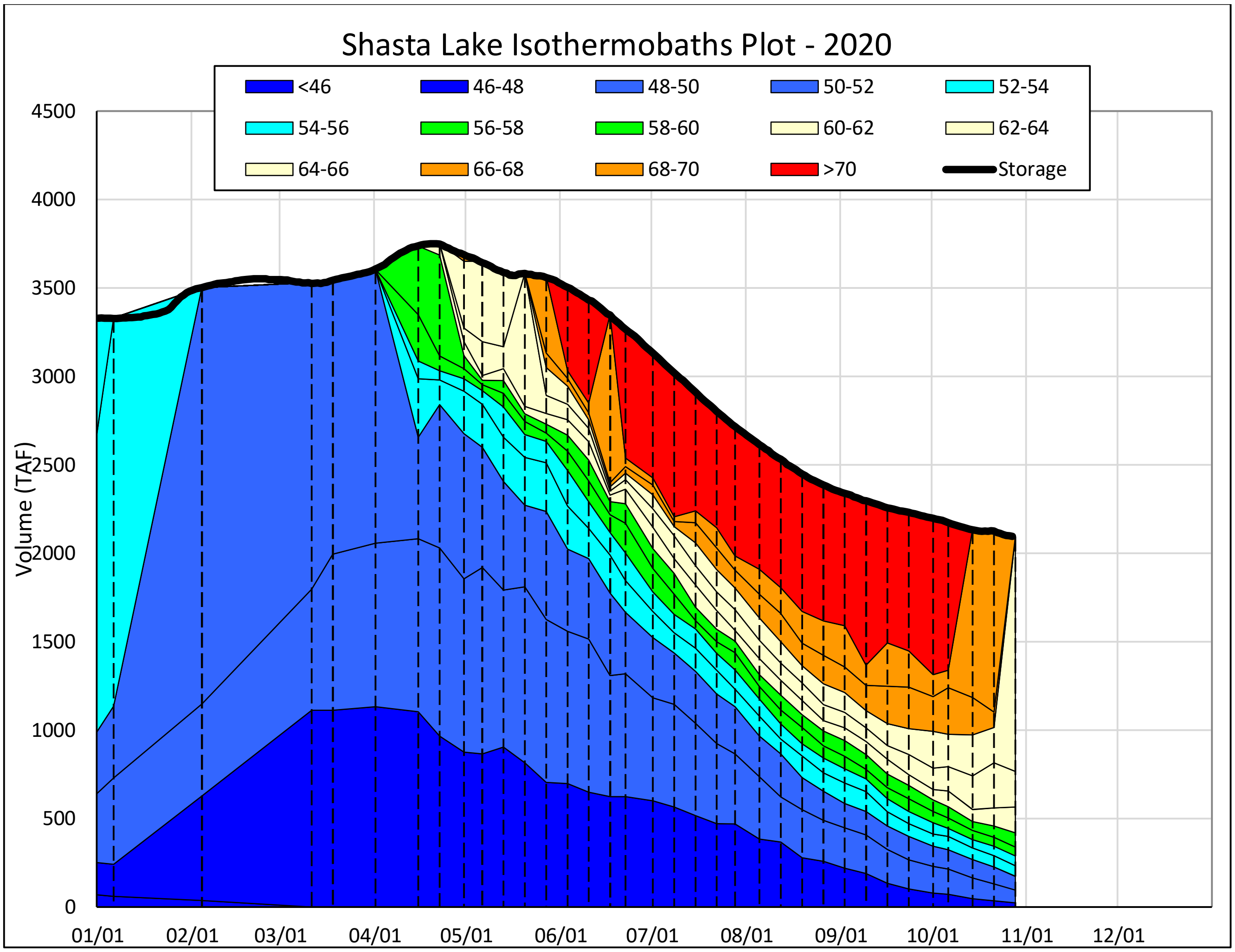

Figure 11. Shasta Lake Isothermobaths Plot from January through October 2020.

As with previous month's evaluations, two forms of insight to future cold water pool management were again assessed: (1) Relationship between total Shasta Lake storage/cold water pool and potential future water temperature compliance; and (2) preliminary water temperature model simulation results. Temperature performance for the year was again slightly improved with storage gains and estimated to be solidly between 54°F-56°F at CCR based on actual May 1 total Shasta Lake storage and cold water pool conditions. Modeling run results of Tier 3 performance, maintaining 53.5°F at CCR for a portion of the season, continue to demonstrate feasible solutions and projected end of September cold water pool volumes suggesting maintenance of water temperature management control in the fall with reasonable timing of TCD Side Gate use. The SRSC also provided additional water temperature simulation modeling support for comparison. A final Sacramento River Temperature Management Plan was submitted May 20, 2020.

Reclamation, in coordination with the SRTTG, chose scenario 148. While the TTSP showed other scenarios may have had lower TDM estimates, these other scenarios did not provide a conservative level of cold water volume at the end of September and/or these other scenarios relied on side gate operations earlier in the season. Opening the side gates too early with insufficient cold water to sustain downstream water temperatures for an extended period results in water temperature warming that cannot be controlled in the fall period. Reclamation considered end of September cold water pool and timing of the side gate operation in addition to modeled biological response in selecting a more conservative approach over the duration of the water temperature management season. Reclamation, in coordination with the SRTTG, chose the scenario having the most end of September cold water pool for similar temperature dependent mortality and side gate criteria as other scenarios evaluated using the TTSP.

The 2020 Temperature Management Plan was implemented beginning May 15, 2020 with the detection of spawned-out female winter-run Chinook salmon. Predicted and actual Shasta Lake cold water pool volumes were tracked as part of the implementation of the Temperature Management Plan. Recommendations for further investigation include analysis of water temperature management prior to the onset of spawning; preliminary analysis suggests cold water pool savings and benefits for the fall period, but it is unknown what pre-spawning impacts may occur (further discussion on this topic is provided in the Discussion section).

June through October

Real-time implementation of the 2020 Temperature Management Plan did not result in any unexpected changes or deviations. In the late spring, runoff and Shasta Lake storage were better than anticipated, improving end of September Shasta Lake storage conditions. June marked a final determination by Reclamation of the Shasta water year type designation. A Shasta non-critical year type was issued; however, due to the late season announcement, there was no significant change in summer diversions, only fall increases in rice decomposition demand water in October and November as a result of Fall Rice Decomposition Smoothing. Monthly simulated water temperature modeling updates were provided to the SRTTG. Summer simulated model alternatives examined delaying TCD Side Gate use or extending summer or fall cooler temperatures. Although opportunities were sought to improve the Temperature Management Plan in early summer, in general the plan was followed as expected as gains were lost as summer persisted. There were no modifications or amendments to the 2020 Temperature Management Plan although an addendum to the plan was circulated to SRTTG on July 31, 2020 and reflected current conditions through July 29,

2020. A summary of Upper Sacramento River temperatures is shown in Figure 12. Change order logs can be found in Appendix C.

The following challenge was illuminated:

- A conservative methodology was applied when estimating water temperature dependent mortality for the TMP. This included using both the physical and empirical models for estimating water temperature in the Upper Sacramento River because there are limitations in the predictions of fall simulated water temperature in the physical model. The approach was to apply the most conservative information (warmest 90% confidence interval expected water temperatures) to project conservative temperature dependent mortality in the fall. At the request of SRTTG members, this methodology was applied consistently for comparison purposes when presenting results from both models throughout the temperature management season. However, this methodology can run counter to exploring benefits that are to be realized in the fall period

In addition, there were three notable events that influenced in-river conditions or real-time operations including:

- Widespread wildfire activity impacted local meteorological conditions including solar radiation and thermal influences. Smoke and haze were unusually prevalent throughout August and September and likely dampened the effects of warm air temperature conditions on reservoir heating and downstream in-river warming.
- TCD Gates: On September 3-4, 2020, Reclamation's Central Valley Office identified a warm water signal in the downstream data suggesting an issue with the Shasta Dam TCD. Reclamation's Northern California Area Office operators sent a Remotely Operated Vehicle on September 4, 2020 to investigate and found TCD Middle Gate #2 and TCD Middle Gate #5 were not fully closed. These gates were reseated to the fully closed position on September 4, 2020. TCD Middle Gate #2 was partially seated from July 13, 2020 – September 4, 2020, and TCD Middle Gate #5 was partially seated from August 6, 2020 – September 4, 2020. Reclamation plans to confirm closure of the TCD Middle Gates in the future.
- TCD Curtain Deployment: To support water temperature management and growing concerns of expected Shasta Dam TCD device performance, Reclamation decided to deploy the Middle Gate TCD curtain. Divers were onsite on September 9, 2020 to install curtains, and on September 16, 2020 divers completed deployment of the curtains. Deployment of the Middle Gate curtain prevents warm water leakage into the TCD, affording more predictable water temperatures downstream.

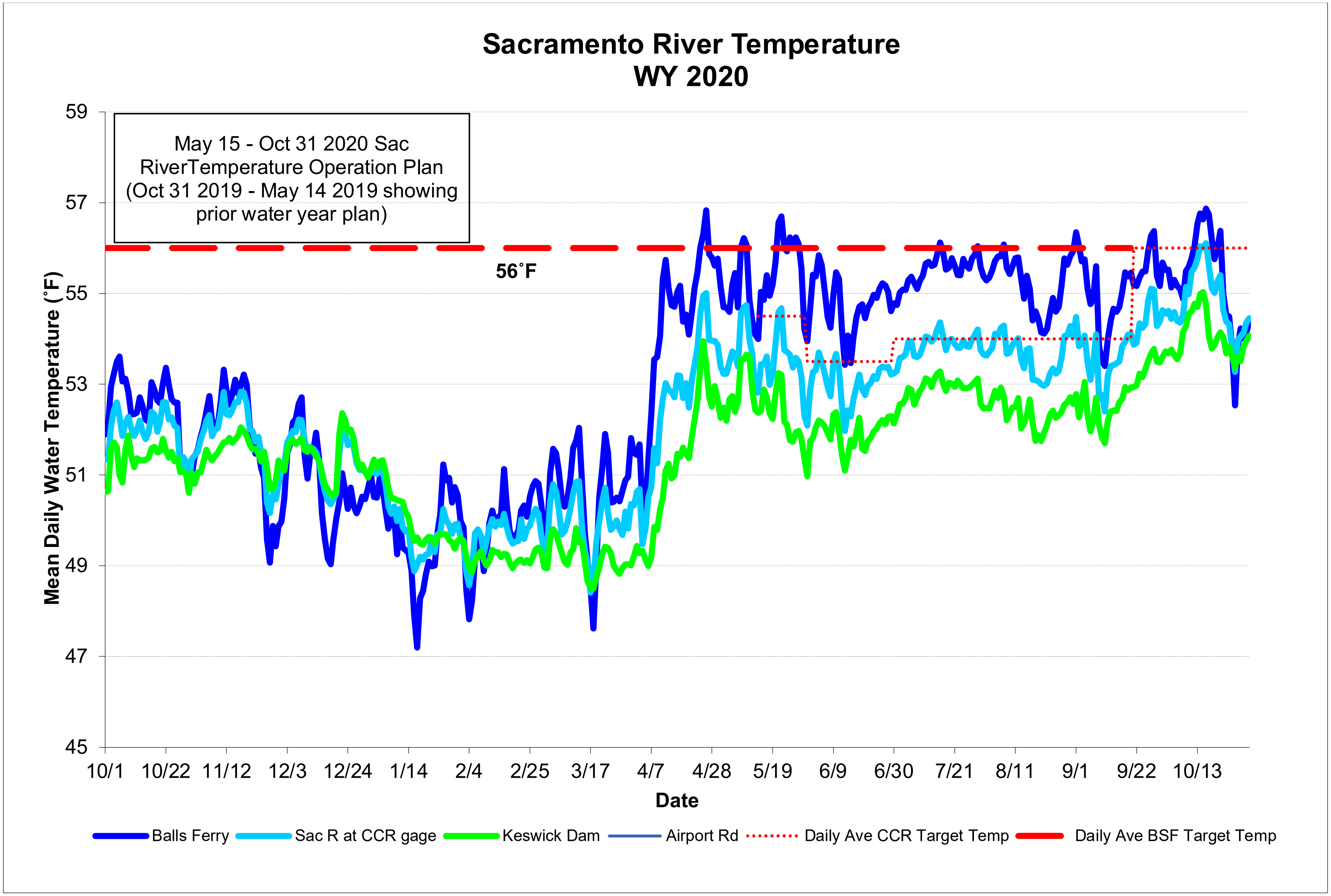

Figure 12. Summary of Upper Sacramento River Daily Mean Water Temperature in WY 2020.

Daily Average Temperature and Temperature Targets

The daily average temperatures performance exceedance for CCR and BSF compliance locations compared against the daily target are shown in Table 4. The average exceedance at CCR was 0.2°F, and the average exceedance at BSF was 0.4°F.

Table 4. Daily Average Temperature Performance Exceedance for CCR and BSF.

Daily Average Temperature Performance Exceedance for CCR and BSF				
Date	Sac R at CCR CCR (°F)	Temp. Target CCR (°F)	Balls Ferry BSF (°F)	Temp. Target BSF (°F)
5/21/2020	54.6	54.5	56.6	56
5/22/2020	54.7	54.5	56.7	56
6/4/2020	53.7	53.5		
6/10/2020	53.7	53.5		
7/11/2020	54.1	54		
7/15/2020	54.2	54		
7/16/2020	54.4	54	56.1	56
7/17/2020	54.1	54		
7/28/2020	54.1	54		
7/29/2020	54.2	54		
8/4/2020[a]	54.1	54		
8/5/2020	54.1	54		
8/6/2020	54.2	54		
8/7/2020	54.3	54	56.1	56
8/28/2020	54.1	54		
8/29/2020	54.1	54		
8/30/2020	54.3	54		
9/1/2020	54.5	54	56.4	56
9/4/2020	54.1	54		
9/8/2020	54.1	54		
9/19/2020	54.1	54		
9/20/2020	54.1	54		
10/16/2020	56.1	56		
Count	23		5	
Min. Exceedance	0.1		0.1	
Max. Exceedance	0.5		0.7	
Ave. Exceedance	0.2		0.4	

[a] 8/4/2020 through 8/7/2020 exceeded three consecutive days. Prior notification was unpredictable, Keswick release reductions and TCD operations were coincident 8/5/2020 through 8/7/2020.

Fisheries

The following section describes the Chinook salmon monitoring efforts undertaken during the WY 2020 temperature management season and juvenile Chinook salmon outmigration.

Chinook Salmon Spawn Timing and Distribution

Four distinct runs of Chinook salmon spawn in the Sacramento-San Joaquin River system, named for the season when the majority of the run enters freshwater as adults. Fall-run Chinook salmon migrate upstream as adults from July through December and spawn from early October through late December. The timing of spawning varies with fall-run Chinook salmon spawning in northern Central Valley streams earlier than the southern Central Valley streams. Late-fall-run Chinook salmon migrate into the rivers from mid-October through December and spawn from January through mid-April. The majority of young salmon of these races migrate to the ocean during the first few months following emergence, although some may remain in freshwater and migrate as yearlings. Spring-run Chinook salmon enter the Sacramento River from late March through September. Adults hold in cool water habitats through the summer, then spawn in the fall from mid-August through early October. Spring-run juveniles migrate soon after emergence as young-of-the-year, or remain in freshwater and migrate as yearlings. Adult Sacramento River winter-run Chinook salmon pass under the Golden Gate Bridge from November through May, and pass into the Sacramento River from December through early August. Winter-run Chinook salmon spawn in the upper mainstem Sacramento River from mid-April through August. Fry and smolts emigrate downstream from July through March of the following year through the Sacramento River, reaching the Delta from September through June of the following year.

Annual population estimates for the Upper Sacramento River Basin are determined through a number of methodologies including carcass surveys, hatchery counts, aerial and in-stream redd surveys, snorkel counts, angler interviews, and video, DIDSON (acoustic sonar) or Vaki Riverwatcher counts in streams and in fish ladders.

Carcass surveys using modern mark-recapture methodologies were initiated in 1996 on the Sacramento River above RBDD using jet boats. Traditionally, the Sacramento River carcass surveys are conducted by boat, each having two or more observers. Three multi-month surveys are conducted each year with crews normally on the river year-round. Survey protocols and methods may change slightly in each survey, but in general terms, the protocols have remained similar since 2003. The late-fall-run Chinook salmon survey begins typically in mid-December and ends in early-May. The winter-run Chinook salmon survey begins in late-April or early-May and ends in late-August or early-September. The all/spring-run Chinook salmon survey begins in early-September and ends in late-December or early-January. The beginning or end of each survey is determined by the number of carcasses observed by the crews at those times. The spawn timing of each run can vary by a few weeks each year so survey dates are flexible and can overlap from one survey to another.

Aircraft are used to conduct monthly surveys for the late-fall-run and fall/spring-run Chinook salmon redd distributions and during the winter-run Chinook salmon spawning period to conduct surveys to enable detailed inspection of winter-run Chinook salmon spawning areas. Aerial redd maps are created by staff on the flights to document the location of spawning areas and distributions in the Sacramento River. These maps are used in conjunction with the corresponding carcass surveys to expand the overall population estimate for each run of salmon. Aerial redd surveys do not

provide complete counts of new redds. Variability in turbidity, river depth, riparian vegetation, weather, and wind all affect the ability of the observer to count new redds. Not all redds that are new are able to be counted but it is assumed that the proportion of redds visible in the various sections during a single flight are identical. The aerial redd data should be used with caution and it is recommended to use aerial redd data only for comparisons of redd distributions by river sections or for specific needs such as use of a specific area as a spawning location.

Preliminary CDFW Upper Sacramento River Basin Salmonid Monitoring Program data for the 2020 temperature management season can be accessed on CalFish:
https://www.calfish.org/ProgramsData/ConservationandManagement/CDFWUpperSacRiverBasinSalmonidMonitoring/tabid/357/Agg2208_SelectTab/4/Default.aspx

These data from the carcass and aerial redd surveys have not yet undergone CDFW's final quality control process to confirm or otherwise verify its accuracy. As a result, this draft data should not be used, relied upon, or referenced in any way until finalized by CDFW. Upon data finalization by CDFW, the draft data available on CalFish will be superseded and deleted. The preliminary data reported here may not be released to any other entity without the express written permission of CDFW.

The following CDFW preliminary information is presented for the 2020 carcass survey and aerial redd survey data for spatial and temporal spawning distribution as it is applicable to Shasta Lake cold water pool and water temperature management for winter-run Chinook salmon is also subject to revision. This summary information is provided as context for focusing on Clear Creek as the spatial water temperature compliance point with temporal compliance beginning May 15, or when the SRTTG determines, based on real-time information, that winter-run Chinook salmon have spawned, whichever is later, and concluding October 31, or when the SRTTG determines based on real-time monitoring that 95 percent of winter-run Chinook salmon eggs have hatched, and alevin have emerged, whichever is earlier.

The CDFW preliminary 2020 winter-run Chinook salmon carcass survey began on May 4th following the same protocols and guidelines as in previous years, were conducted weekly, and concluded on October 10th. Temporal distribution of carcasses is as follows: the first carcass was detected on May 6th (0.1% of the cumulative total), 1842 carcasses (50.1% cumulative) were detected by July 15th, 3500 carcasses (95.2% cumulative), were detected by August 12th, and 3,678 carcasses (100% cumulative) were detected by September 24th.

The distribution of carcasses by area (Table 5) indicates that 42.7 percent of carcasses were collected between Keswick Dam and the ACID Dam which is higher than the 2003-2019 average. The percent of carcasses collected from the ACID Dam to the Highway 44 Bridge was 33.7% which is lower than the 2003-2019 average of 38.7%. The percentage of carcasses collected from the Highway 44 Bridge to the Clear Creek Powerlines was 20.2% and the percent collected from Clear Creek Powerlines to the Balls Ferry Bridge was 3.4% which are generally similar to the 2003-2019 averages. These CDFW preliminary data are as of July 30, 2020 and are likely to be revised after CDFW completes its QAQC process. Overall, 96.6% of carcasses were collected above the vicinity of the Clear Creek temperature compliance point and 3.4% were collected below the vicinity of the Clear Creek temperature compliance point. However, because carcasses are known to drift downstream from the location where the fish spawned, these data are inconclusive as to whether winter-run Chinook salmon spawned below the Clear Creek temperature compliance point. Aerial

redd surveys provide another line of evidence for spawning distribution which should be considered in conjunction with carcass survey data.

Table 5. Winter-run Chinook salmon carcass count by river area in 2020.

NOTE this data is preliminary and subject to change during final analysis that occurs after the season is completed

2020 Winter-Run Carcass counts by river area as of 7-30-20				
Section	river miles	Carcasses	2020 Percent	% Average (2003-2019)
1- Keswick Dam to ACID Dam (rm 302 to 298)	302-298	1569	42.7%	34.4%
2- ACID Dam to Hwy 44 Brg (rm 296)	298-296	1240	33.7%	38.7%
3- Hwy 44 Brg down to Clear Crk Powerlines (rm 288)	296-288	743	20.2%	22.6%
4- Clear Crk Pwrl to Balls Ferry Brg (rm 276)	288-276	126	3.4%	4.4%
Total	26 miles	3,678	100.0%	100.0%

The first winter-run Chinook salmon aerial redd survey was conducted on May 27, 2020 and the final survey was conducted on August 18, 2020. A total of 11 surveys were conducted weekly through July 7, 2020 and bi-weekly from July 14, 2020 through August 12, 2020. The results of these surveys indicate that redds distribution was concentrated upstream of the Highway 44 Bridge with no indication of redd distribution below the vicinity of the Clear Creek temperature compliance point (Table 6).

Table 6. Winter-run Chinook salmon aerial redd survey counts by river area in 2020.

2020 Winter-Run aerial Redd counts by river area as of 9-1-20					
Flight Sections		river mile	Redds	2020 Percent	% Average (2003-2019)
Keswick to A.C.I.D. Dam.	Carcass Section 1	298	229	47%	37.8343841771605%
A.C.I.D. Dam to Highway 44 Bridge.	Carcass Section 2	296	226	46%	49.2%
Highway 44 Br. to below Clear Crk	Carcass Section 3	284	36	7%	12.5%
Below Clear Crk. to Balls Ferry Br.	Carcass Section 4	275	0	0%	0.0%
Balls Ferry Br. to Battle Creek.	Below Carcass	271	0	0%	0.0%
Battle Creek to Jellys Ferry Br.	Below Carcass	266	0	0%	0.2%
Jellys Ferry Br. to Bend Bridge	Below Carcass	257	0	0%	0.1%
Bend Bridge to Red Bluff Diversion Dam	Below Carcass	242	0	0%	0.1%
Red Bluff Diversion Dam to Tehama Br.	Below Carcass	229	n/s	n/s	0.0%
		total	491	100%	100%

The 2020 winter-run Chinook salmon redd distribution is consistent with the long-term trend of redd distribution upstream of the Clear Creek temperature compliance point with the notable exceptions 2019 (21% below CCR compliance point) and 2016 (22.2%) (Table 7).

Table 7. Percent of winter-run Chinook salmon redds downstream of CCR gauge near Bonnyview Bridge (1989-2020).

YEAR	Percent of Winter-runs redds downstream of the CCR gauge near Bonnyview Bridge
2020	In Progress but so far 0%
2019	21.0%
2018	0.5%
2017	0.0%
2016	22.2%
2015	0.0%
2014	2.4%
2013	0.2%
2012	0.0%
2011	0.0%
2010	1.8%
2009	0.0%
2008	0.2%
2007	5.9%
2006	7.1%
2005	5.7%
2004	19.3%
2003	8.2%
2002	13.8%
2001	26.7%
2000	39.0%
1999	38.4%
1998	9.2%
1997	10.0%
1996	16.3%
1995	5.7%
1994	56.3%
1993	25.0%
1992	46.3%
1991	10.0%
1990	39.4%
1989	25.5%
1988	58.3%

Preliminary results show an in-river spawner number between 3,900-4,000 fish. A final estimate will be available shortly after completion of hatchery evaluation analysis and Livingston Stone National Fish Hatchery data. Environmental conditions (mainly clear water) during the survey this year allowed crews to collect more carcasses but also aided in recapturing the tagged carcasses. The final estimate is based upon the recapture of marked carcasses with the greater the proportion of recaptures resulting in a lower estimate than for 2019 despite more carcasses being collected in 2020. As of September 1, 2020, the percentage of hatchery-origin winter-run Chinook salmon collected during carcass survey was approximately 47% which is higher than desirable but not as high as the years after the drought (80% for two years).

Juvenile Chinook Salmon Outmigration

A natural winter-run Chinook salmon juvenile production estimate (JPE) is calculated annually and historically has delivered late winter (January or February). There is not a current winter-run Chinook salmon JPE for WY 2021 (Brood Year BY 2020). The JPE is typically available in January or February each year. Estimated daily and biweekly passage of juvenile winter-run Chinook salmon at Red Bluff Diversion Dam from 07/01/2020 to 11/03/2020 is shown in Figure 13. Historical and current estimated passage of juvenile winter-run Chinook salmon at Red Bluff Diversion Dam (BY 2014 – BY 2020) is shown in Figure 14.

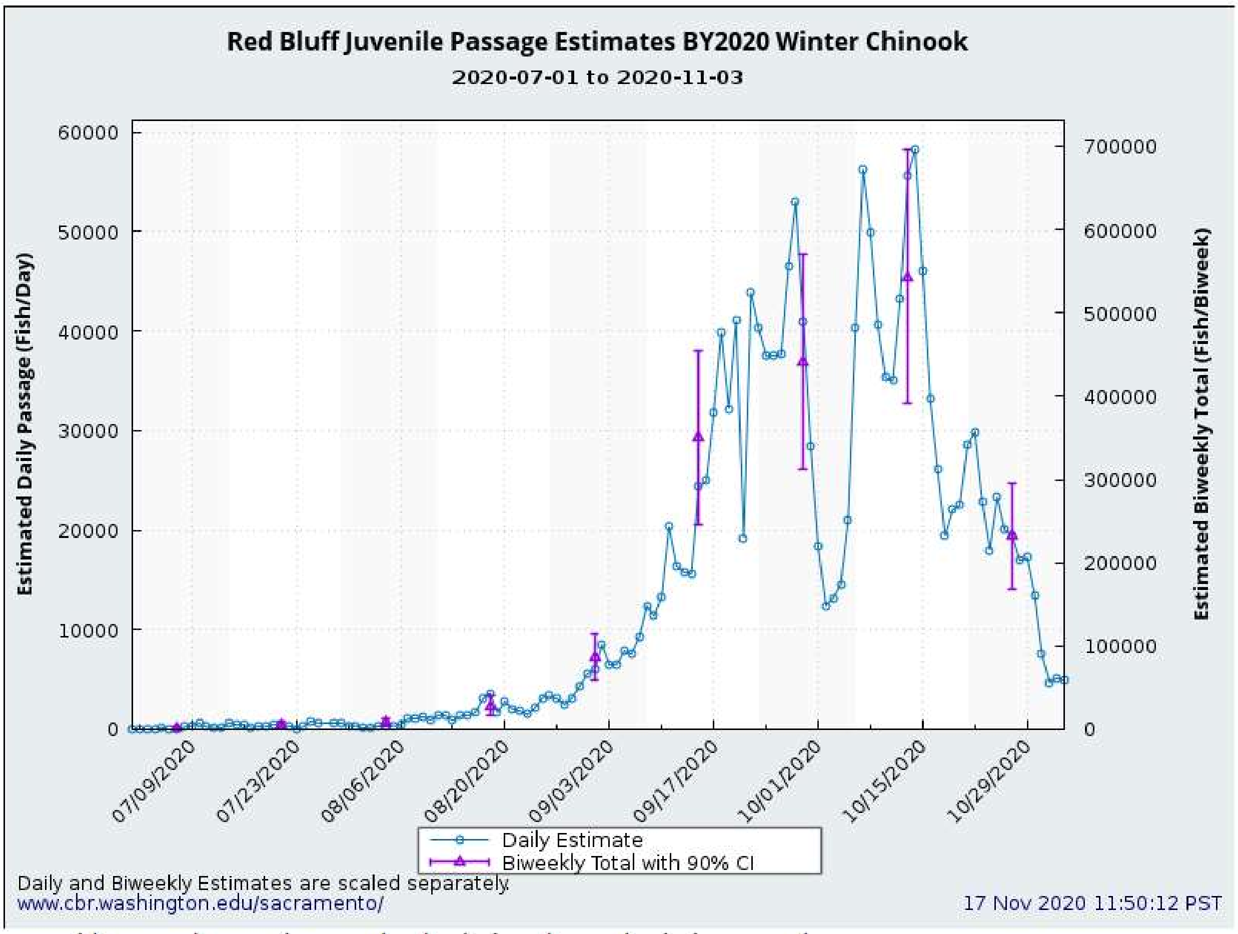

Figure 13. Daily and Biweekly (Total with 90% Confidence Interval) Estimates of Juvenile Winter-run Chinook Salmon Passage at Red Bluff from 07/01/2020 - 11/03/2020.

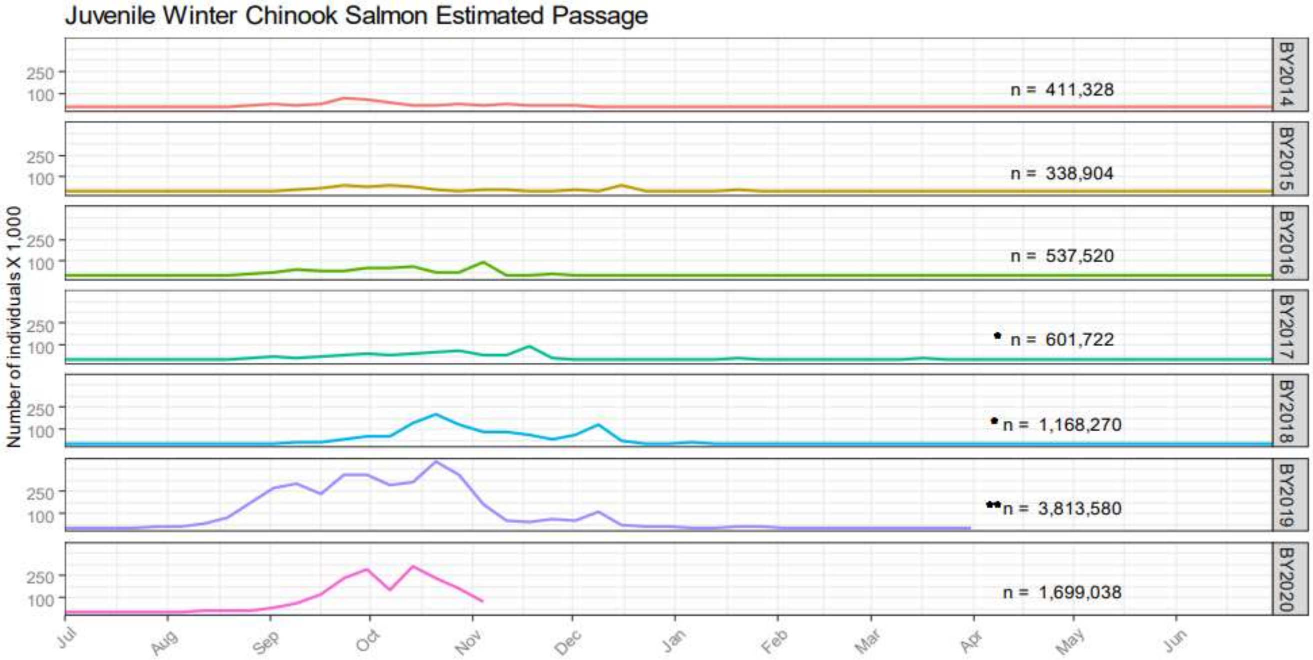

Figure 1. Weekly estimated passage of unmarked juvenile winter Chinook salmon at Red Bluff Diversion Dam (RK391) by brood-year (BY). Fish were sampled using rotary-screw traps for the period July 1, 2014 to present.

*Winter Chinook passage value reflects addition of length-at-date spring Chinook determined to be winter Chinook from genetic analysis during the period of October 16th thru November 18th during brood years 2017 thru 2019. See memos on 2018 & 2019 biweekly report pages for more info.

**Rotary-trapping/juvenile fish monitoring operations at the Red Bluff Diversion Dam were suspended from March 25, 2020 to June 30, 2020, to protect employee health and safety resulting from the Coronavirus/COVID-19 global pandemic.

Figure 14. Historical and Current Estimated Passage of Juvenile Winter-run Chinook Salmon at Red Bluff Diversion Dam (BY 2014 - BY 2020).

Operations Summary

Key events of the 2020 cold water pool temperature management season:

- The 2020 Water Temperature Plan detailed a Tier 3 performance category and specified both temperature targets and locations.
- Initiation of the water temperature management season began on May 15, 2020 with detection of spawned-out winter-run Chinook salmon females.
- Opening of the first side gate on August 13, 2020.
- End of September Cold water pool volume less than 56°F was 476 TAF.
- Termination of the water temperature management season was on October 31, 2020. Firm data supporting a total population for year 2020 winter-run Chinook salmon population was unavailable in real-time to calculate the date of 95% hatch and alevin emergence.
- No modification or amendment to the 2020 Water Temperature Plan was necessary.

Performance

In order to determine the accuracy of the water temperature model (e.g. HEC-5Q) and the water temperature-dependent egg mortality models (e.g. Anderson model and Martin models) used to forecast Shasta Lake cold water pool operations, Reclamation performed a hindcast review of these models using actual data observed.

Models

A discussion of the models used for temperature and temperature-dependent egg mortality, as well as a discussion of how these models performed during the WY 2020 temperature management season is included below.

Temperature Forecast and Hindcast

A seasonal water temperature forecast describes future expected downstream water temperature. This forecast, or simulation of expected water temperature performance is based on the targets specified in the TMP. Future water temperature is forecasted using computational tools, at various elevations in the reservoirs and downstream in the river. These tools are based on conservative assumptions regarding hydrology, operations and meteorology. Because this forecast (using conservative estimates in April to estimate what might happen at the end of October) can never exactly predict the actual hydrology, operations, and meteorology in advance, the model results are not expected to precisely match actual water temperatures. The expectation is, however, that forecasted downstream water temperature generally have an accepted measure of error regardless of the uncertain future conditions. In this case, there are generally two types of simulation error; uncertainty of the future conditions (e.g. inputs such as meteorology) and inherent model error or bias. To better understand the inherent model error or bias, a hindcast evaluation is typically performed. A hindcast, rather than looking forward to forecast, simply uses the actual input/forcing data after it's observed (e.g. hydrology, operations, and meteorology) to determine how well the model reproduced a condition such as actual downstream water temperatures. This resulting analysis describes how well the model performs given perfect foresight.

Methods

The hindcast effort was motivated by a desire to test the HEC-5Q temperature model in forecasts for the Sacramento River Temperature Task Group against year 2020 observed data. Input data from April 15 to October 31 (the run period of the hindcast) were used for river flows from California Data Exchange Center and United States Geological Survey gages. Temperature targets from the same period were set at the actual temperature at the TCD as measured. Initial vertical temperature profiles for Shasta, Whiskeytown, and Trinity reservoirs were used from dates as close to April 15 as possible. Observed 2020 meteorology data was compiled by RMA Engineers. A comparison of calculated equilibrium temperature (blue) to the forecasted equilibrium temperature used in a forecast run made on April 15 (red) at a 6-hourly time scale is shown in Figure 15.

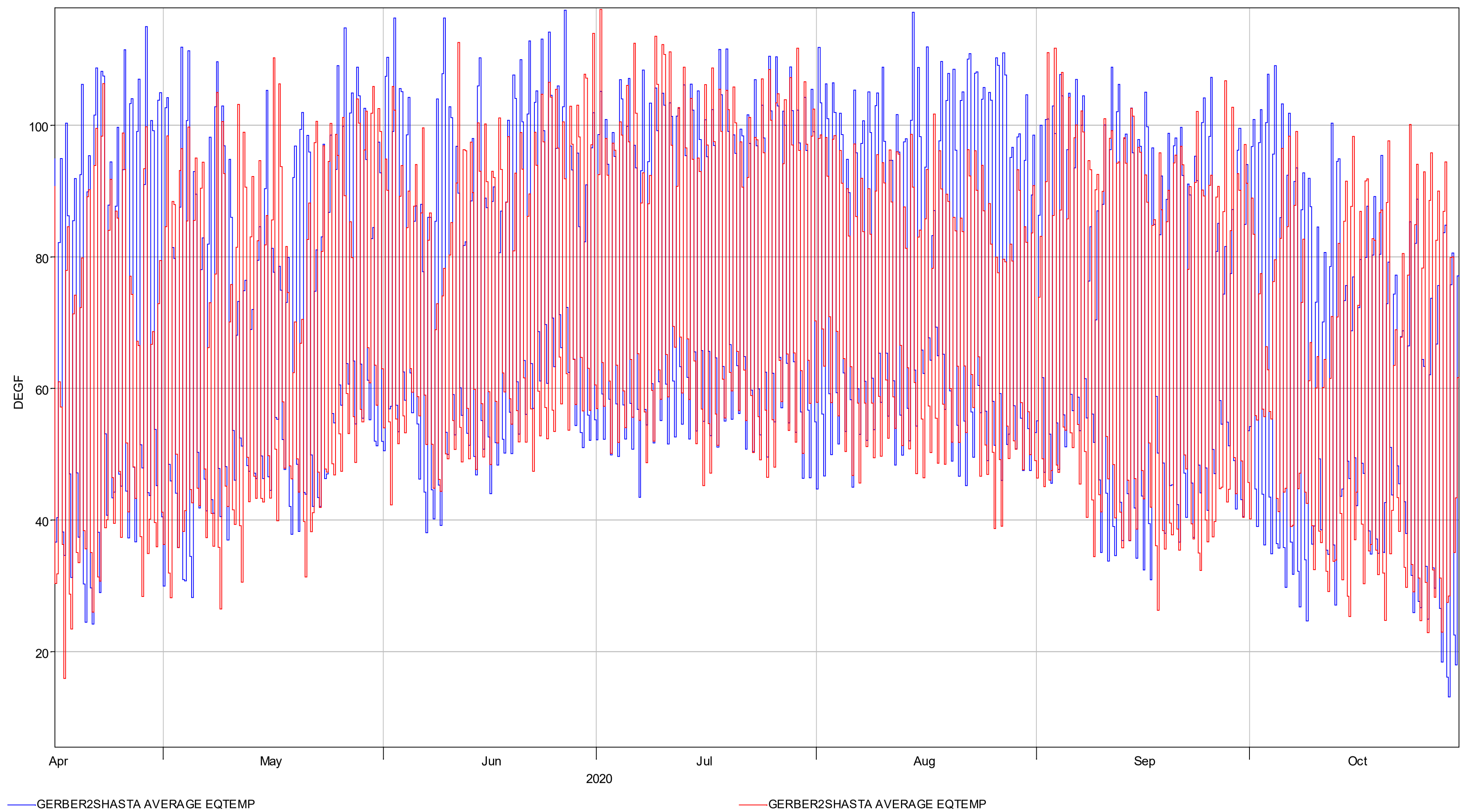

Figure 15. WY 2020 comparison of calculated equilibrium temperature (blue) to the forecasted equilibrium temperature used in a forecast run made on April 15 (red) at a 6-hourly time scale

Results
Modeled vertical temperature profiles for Shasta Lake and downstream Sacramento River temperatures were compared to 2020 observed data. Four error metrics were calculated for each comparison: Mean bias, Mean Average Error, Root Mean Squared Error, and Nash-Sutcliffe Efficiency. Vertical temperature profile comparison results are shown in Table 8. Error metrics were also calculated with the upper 30 feet of the Shasta Lake profile removed. This was for the purpose of discounting for surface dynamics to evaluate goodness of fit at levels from which water is drawn by the TCD (Table 9). Modeled and historical vertical temperature profiles for Shasta Lake on 7/1/2020 is shown in Figure 16. Figure 16. Modeled and observed vertical temperature profile of Shasta Lake on 7/1/2020.

Table 8. Errors metrics used to compare modeled vertical temperature profiles for Shasta Lake and Sacramento River temperatures to 2020 observed data. Metrics include Mean Bias, Mean Average Error (MAE), Root Mean Squared Error (RMSE), and Nash-Sutcliffe Efficiency (NSE).

Date	**4/30**	**5/27**	**7/1**	**7/22**	**7/28**	**9/2**	**10/1**	**10/14**	**10/28**
Mean Bias	0.0488	0.2427	0.0358	0.2619	0.2170	0.3773	2.2361	-0.0513	-0.2159
MAE	0.5202	0.6489	0.6033	0.8344	0.9003	1.3375	2.3708	2.2963	2.7829
RMSE	1.0374	1.3407	1.2306	1.6406	1.8732	2.6783	3.5948	3.3519	3.4158
NSE	0.9266	0.9444	0.9805	0.9723	0.9680	0.9364	0.8258	0.8398	0.7686

Table 9. Error metrics used to compare modeled vertical temperature profiles for Shasta Lake (excluding the upper 30 feet) and Sacramento River temperatures to 2020 observed data. Metrics include Mean Bias, Mean Average Error (MAE), Root Mean Squared Error (RMSE), and Nash-Sutcliffe Efficiency (NSE).

Date	**4/30**	**5/27**	**7/1**	**7/22**	**7/28**	**9/2**	**10/1**	**10/14**	**10/28**
Mean Bias	-0.2111	-0.0656	-0.1936	-0.1512	-0.1661	-0.3559	1.5617	-0.9242	-0.8907
MAE	0.2987	0.3736	0.3278	0.4723	0.4723	0.6958	1.7105	1.6558	2.4069
RMSE	0.3983	0.6246	0.4805	0.7293	0.7152	1.0197	2.5300	2.1772	2.9237
NSE	0.9563	0.9596	0.9926	0.9875	0.9899	0.9860	0.8813	0.9234	0.8240

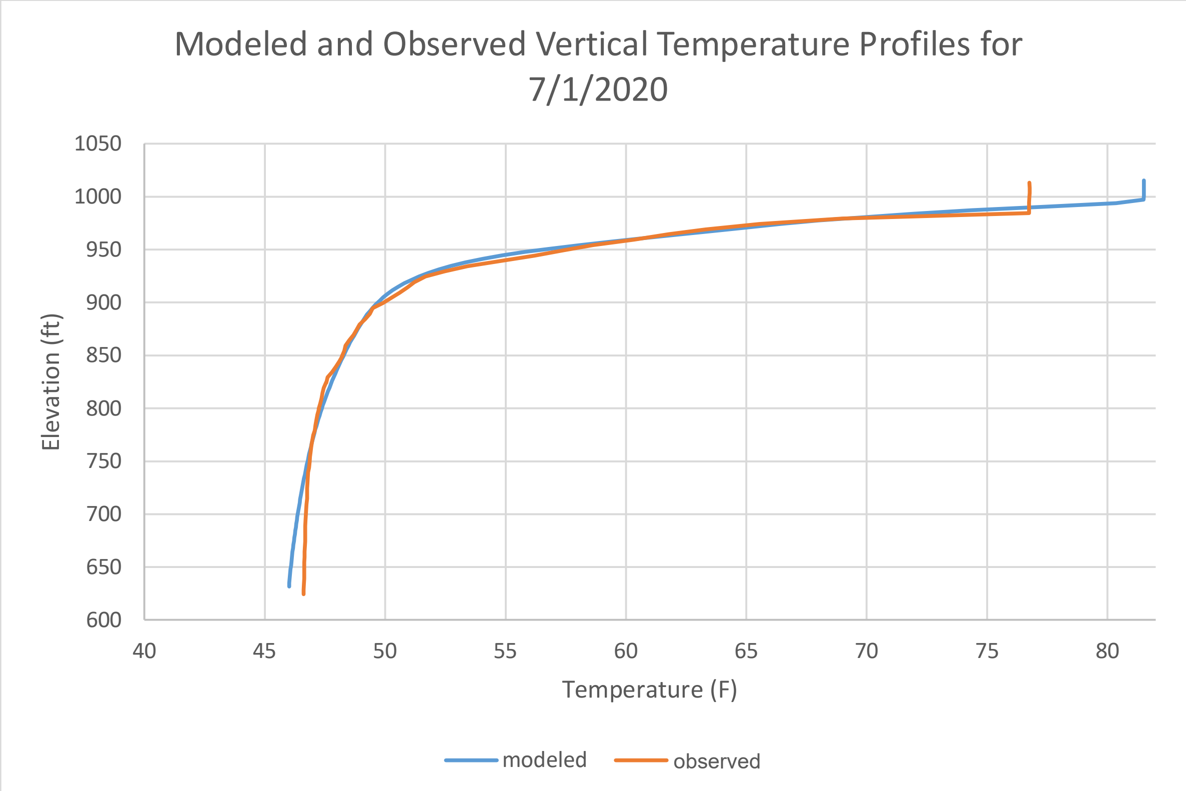

Figure 16. Modeled and observed vertical temperature profile of Shasta Lake on 7/1/2020.

For hindcast evaluation, modeled and actual water temperatures at three locations were compared: Sacramento River at Keswick Dam (Figure 17), Clear Creek (Figure 18), and Balls Ferry (Figure 19). While the Clear Creek and Balls Ferry locations exhibited low error and close matching with the actual observed time series data, Keswick Dam forecasted model outputs were about 1-degree F warmer than 2020 observed data throughout the time series.

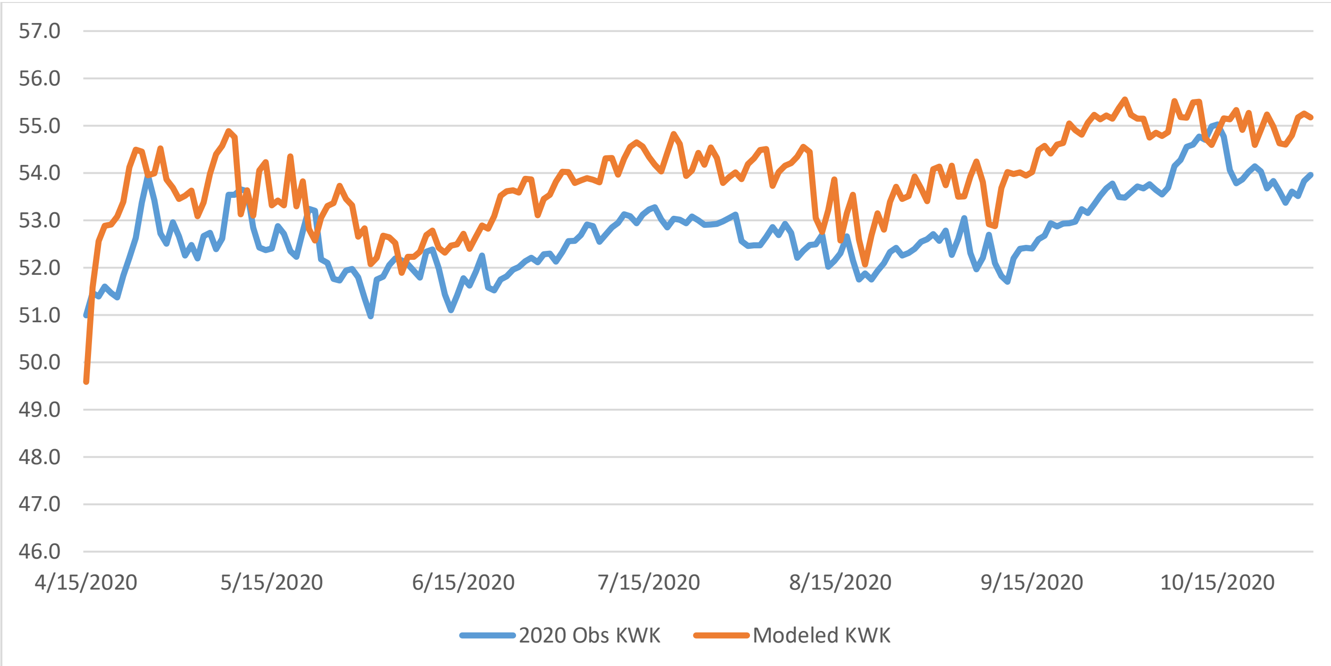

Figure 17. Modeled and observed water temperatures at Keswick (KWK) from 4/15/2020 - 10/31/2020.

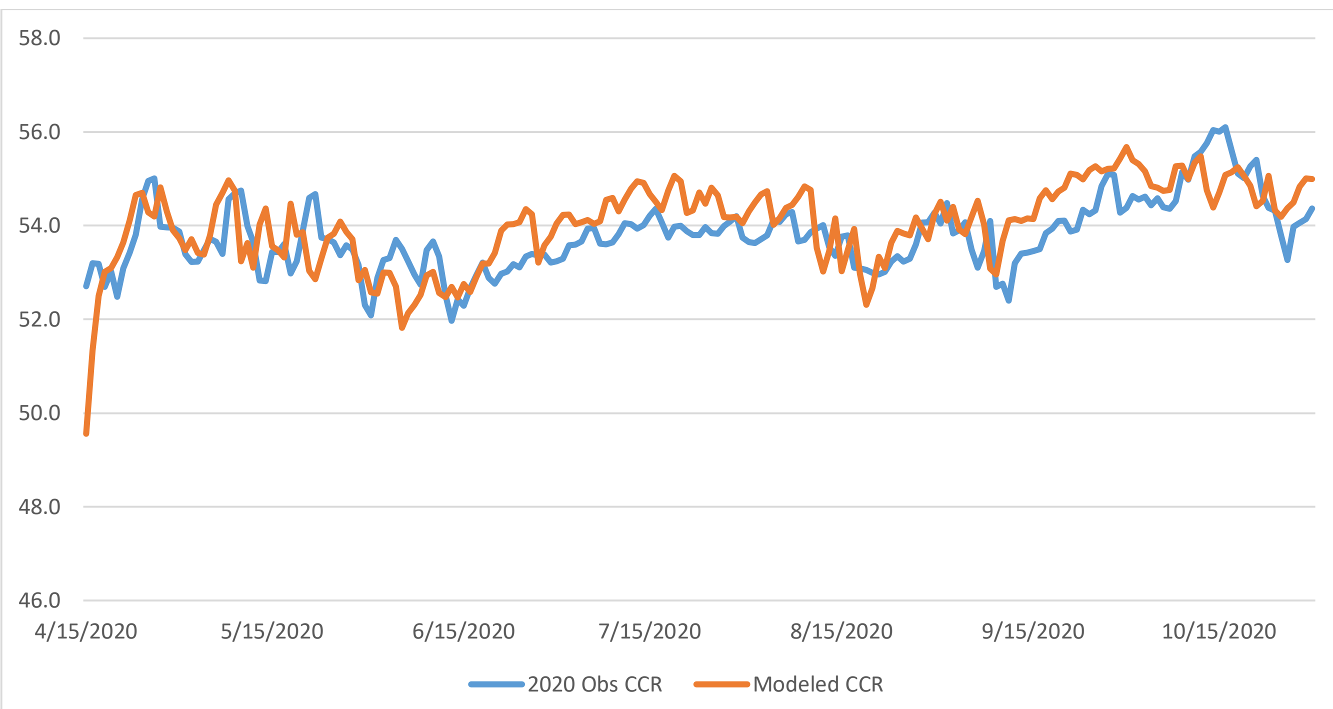

Figure 18. Modeled and observed water temperatures at Clear Creek (CCR) from 4/15/2020 - 10/31/2020.

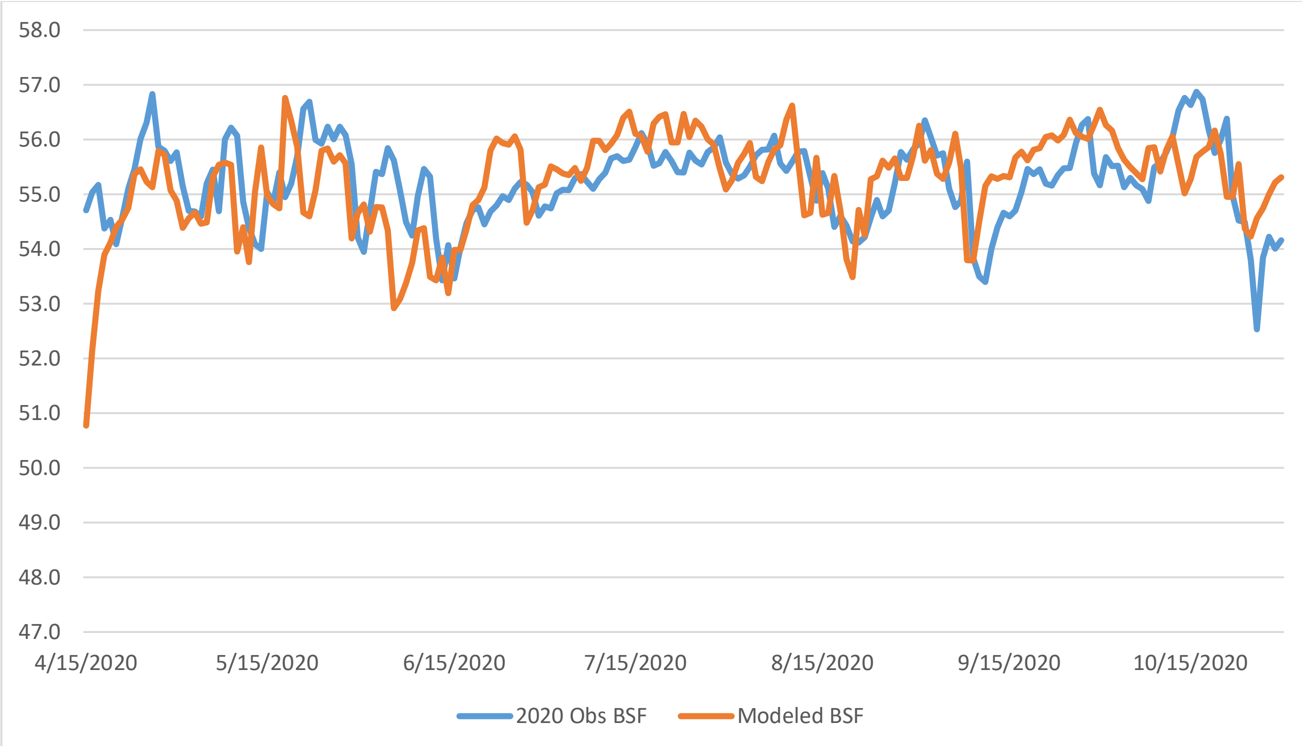

Figure 19. Modeled and observed water temperatures at Balls Ferry (BSF) from 4/15/2020 - 10/31/2020.

This section answers the question of how well the 2020 Temperature Management Plan performed from a cold water pool perspective. Figure 20 compares the modeled prediction of Shasta cold water pool less than 49°F with actual conditions. The model run depicts the May 20, 2020, 90% runoff exceedance hydrology and operations outlook with 25% meteorological conditions (conservative assumption of a dry and warm environment). This graphic was updated weekly and provided to SRTTG to allow for transparency and confidence in the actual performance of the Temperature Management Plan.

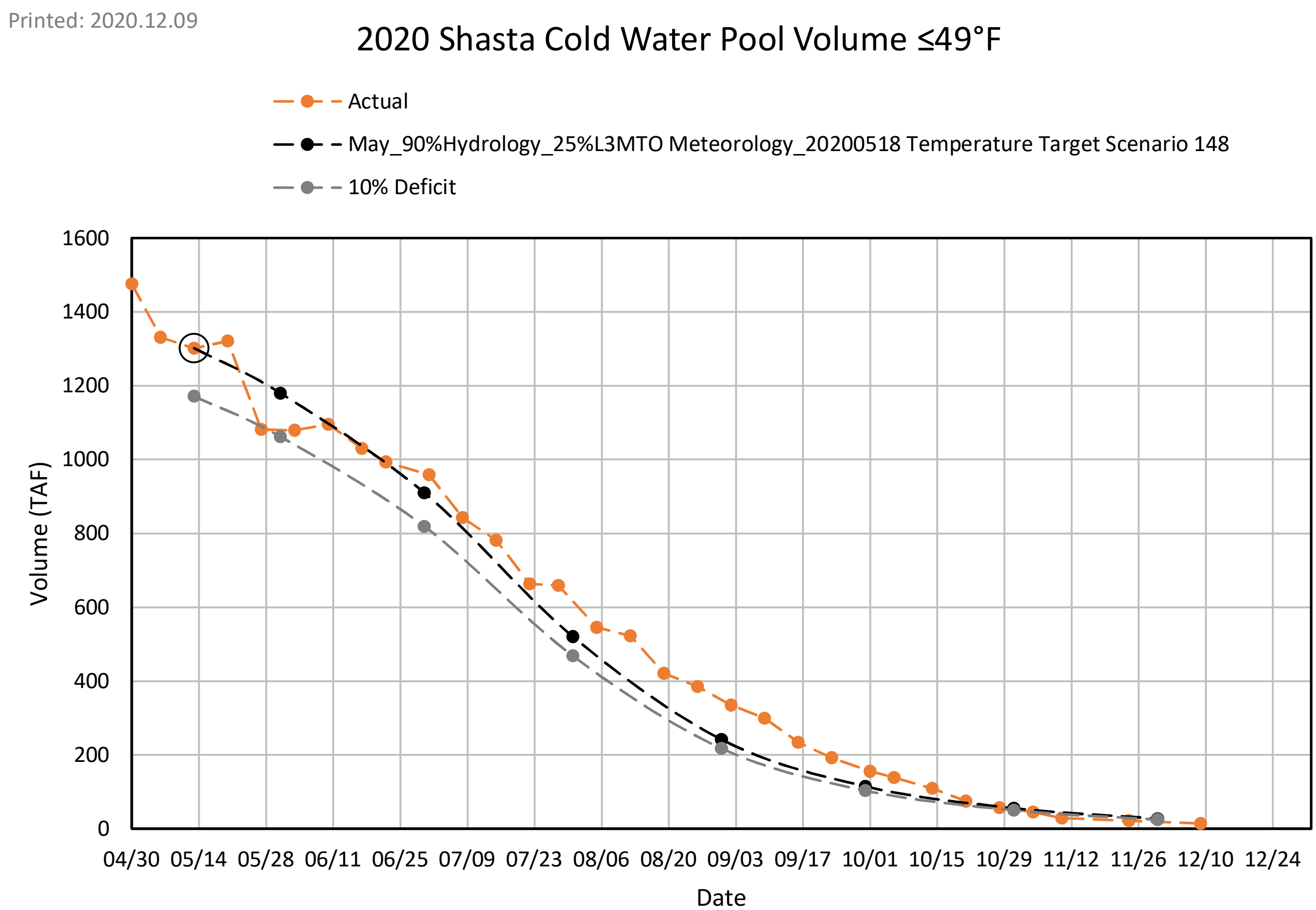

Figure 20. Actual and Predicted Shasta Cold Water Pool Volume (less than or equal to 49F) during the WY2020 Temperature Management Season.

Temperature Dependent Mortality Forecasts

Both Reclamation and NMFS provided water temperatures dependent egg mortality forecasts.

Reclamation's approach uses spatially-explicit daily average Sacramento River water temperature forecasts from the HEC-5Q model results and an empirical relationship as inputs to generate water temperature dependent egg mortality estimates. When available, historical water temperature data is used to capture actual observed temperature during the early water temperature management period. Historical temperatures on the Sacramento River at Shasta Dam, Keswick Dam, above Clear Creek, Balls Ferry, Jelly's Ferry, and Bend Bridge are interpolated to estimate temperatures at river miles where simulated redds were located. Between September 15 and October 31, daily water temperatures at the simulated redds' river miles are estimated based on an empirical relationship between cold water pool volume less than 56°F at the end of September in Shasta Lake and water temperatures above Clear Creek derived by Central Valley Operations. Reclamation finds this relationship is more reliable in that time period than outputs from the HEC-5Q model (previous evaluations suggest a stronger underestimating bias in October than September). The 90% confidence interval value from this analysis was used as a conservative estimate. The average difference between the simulated temperatures above Clear Creek and the simulated temperatures at

the redds' river miles during this period are used to adjust above Clear Creek estimated water temperatures for each river mile.

Temperature-dependent egg mortality estimates were calculated by modeling a redd's lifetime based on the days required to cross a known cumulative degree-day threshold and estimating mortality as an increasing function of water temperature past a temperature threshold. Two models were used: (1) Martin et al (2017) for stage independent modeling whereby a single temperature threshold is used from spawning and incubation through emergence; and (2) Anderson et al. (2018) for stage dependent modeling for targeting different water temperatures before, during, and after the most sensitive stages during egg incubation. The Anderson Model provides an input parameter that factors in eggs needing more oxygen as they develop and are more sensitive immediately prior to hatching due to increased biological demand of oxygen.

The TDM forecasting methods were applied to a set of simulated redds representative of redd construction timing and location from 2007-2014 and the results summarized on a seasonal level for comparison (Appendix D; Table A1). TDM estimates varied depending on the temperatures and TDM models used (Table 10).

Table 10. Reclamation and NMFS Temperature Dependent Mortality Estimates Throughout the WY2020 Temperature Management Season using the Stage Dependent (Anderson) and Stage Independent (Martin) Models.

Date	Reclamation Stage Dependent TDM Estimate (%)	Reclamation Stage Independent TDM Estimate (%)	NMFS Stage Independent TDM Mean Estimate (%)	NMFS Stage Independent TDM Median Estimate (%)	NMFS Stage Independent TDM Lower Estimate (%)	NMFS Stage Independent TDM Upper Estimate (%)
4/22/2020	18.6	27.5	NA	NA	NA	NA
5/20/2020	14.8	27.9	NA	NA	NA	NA
5/25/2020	NA	NA	30.63	27.57	0.08	69.6
6/22/2020	19.2	30.5	34.9	33.83	0.27	71.34
7/17/2020	17.9	25.8	29.4	26.2	0.2	67.9
8/25/2020	9.8	24.7	24.8	21.9	0.2	63.1
9/21/2020	9.5	24.7	19.4	16.9	0.1	56.3
10/22/2020	9.5	26	11.78	6.36	0.11	53.31

Temperature Dependent Mortality Hindcast

TDM hindcasts methods are similar to TDM forecasts described above. The SacPAS Fish model allows modeling of spawning to emergence in the Sacramento River. Historic winter-run Chinook salmon redd and temperature data are inputs and survival from redd to Red Bluff Diversion Dam can be modeled as a function of stage-independent (Martin et al. 2016) or stage-dependent (Anderson 2018) mortality. The SacPAS Fish Model was used to provide hindcast TDM estimates described below. SacPAS is further described in the Analysis Tools section.

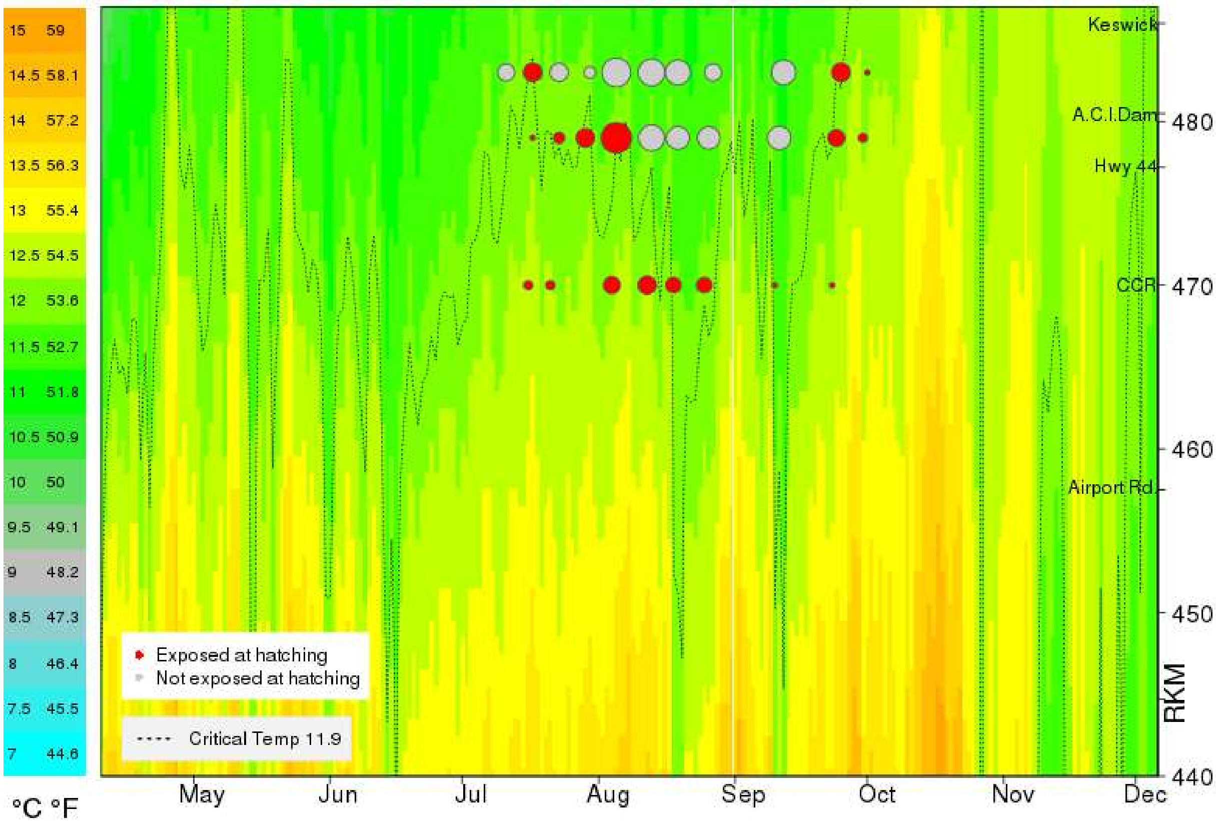

Figure 21. WY 2020 distribution and timing of winter-run Chinook salmon hatching with water temperatures using Stage Dependent Mortality Model and other model inputs described in Appendix D; Table 2A. Winter-run Chinook salmon redds exposed to water temperatures that exceed critical temperature threshold during hatch time in redd. Gray circles indicate winter-run Chinook salmon redds that were not exposed to water temperatures that exceeded critical water temperature threshold indicated in gray. Size of circles reflect number of redds (e.g., larger circles indicate that there were a larger number of redds at the time and location.

Winter-run Chinook salmon redds further downstream are exposed to water temperatures that are warmer. The SacPAS Fish Model has the ability to describe temperature dependent mortality for redds in general locations. The redds downstream near Clear Creek were exposed to water temperatures above the critical temperature (53.5°F). Water temperature dependent mortality hindcasts for redds near Clear Creek (RKM 470) ranged from 0% to 58.2% using the Stage Independent Mortality Model, and 19.5% to 52.4% using the Stage Dependent Mortality Model (Appendix D; Tables 5A and 8A).

Reclamation's Mortality forecasted estimates for overall temperature dependent mortality ranged from 24.7% to 27.5% using the Stage Independent Model, while overall Stage Dependent Mortality Estimates ranged from 9.5% to 19.2% (Table 5). Reclamation's Hindcast of total TDM estimates ranged from 3.0% to 7.2%.

Hindcast estimates for WY 2020 winter-run Chinook temperature-dependent mortality from the NMFS Southwest Fisheries Science Center are included in Appendix E.

Performance Metrics

This section discusses the Upper Sacramento Performance Metrics included in the ROD for water temperature dependent mortality and egg-to-fry survival.

Estimates of Temperature Dependent Mortality

The 2020 ROD includes the following Upper Sacramento Performance Metrics for water temperature dependent mortality estimates:

- Tier 1 – Maximum (39%); Average (6%); Median (2%); Minimum (0.4%); Std. Dev (+/-9%)
- Tier 2 - Maximum (46%); Average (15%); Median (9%); Minimum (1%); Std. Dev (+/-16%)
- Tier 3 - Maximum (77%); Average (34%); Median (24%); Minimum (6%); Std. Dev (+/-31%)

Reclamation's Hindcast TDM estimates ranged from 3.0% to 7.2%. These results indicate that Tier 3 performance criteria were met. Additionally, the Tier 2 Upper Sacramento River Performance Metric for TDM was also met.

When providing forecasts of water temperature dependent egg mortality for winter-run Chinook salmon, Reclamation and NMFS rely on previous year's redd data and water temperature data as inputs for these forecasts. When 2020 redd data was replaced with the redd data (2007-2014) used for forecasted TDM estimates, Reclamation estimated TDM of 2.7% and 6.6% (Appendix D; Table 9A). These similar TDM estimates indicate that the redd data distribution used for TDM forecasts appears to be representative of this year's redd data distribution and captured that the majority of the redds were upstream of the temperature compliance locations. As Figure 17, Figure 18, and Figure 19 indicate, the water temperature models overestimated the water temperatures resulting in an overestimate of temperature dependent egg mortality, especially at Keswick Dam. As the year progresses, we incorporate actual temperature data as it becomes available to refine the models.

The water temperature dependent mortality hindcasts indicate that water temperature dependent egg mortality was low this year (3.0% and 7.2%), much lower than the forecasted estimates made throughout the water temperature management season. WY 2020 was categorized as a Tier 3. The NMFS Biological Opinion (page 276) describes that in a Tier 3 Year, 53.5°F is expected to be exceeded 65 percent of the days. This exposure was expected to result in an estimated water temperature-dependent mortality in Tier 3 Years of 28 percent and 34 percent for the Anderson (i.e., Stage Dependent) and Martin (i.e., Stage Independent) Models. The water temperature dependent egg mortality hindcast was much lower (3.0 and 7.2%).

Estimates of Overall Egg-to-Fry Survival at Red Bluff

Many factors contribute to early life stage survival of salmonids, such as predation, water temperature, water quality, and density dependent effects. In 2019 and 2020, high incidences of thiamine vitamin deficiency have been reported to contribute the mortality of early life stages of

Chinook salmon. The ROD includes the following Upper Sacramento Performance Metrics for egg-to-fry survival:

- Tier 1 - Average (29%); Maximum (49%); Minimum (15%); Median (28%); Std. Dev (10%)
- Tier 2/3 - Average (21%); Maximum (34%); Minimum (15%); Median (20%); Std. Dev (6%)
- Tier 4 - Appropriate performance metrics will be addressed under "Drought and Dry Year Actions" consistent with the "Governance" section

The information to assess winter-run Chinook salmon egg-to-fry survival is not currently available as the brood year 2020 winter-run Chinook salmon juvenile production estimate has not yet been released by NMFS. Reclamation may provide supplemental information with updated egg-to-fry survival values or provide the updated values in a subsequent seasonal report.

The SacPAS Fish Model was used to estimate egg-to fry survival. Egg-to-fry survival to Red Bluff Diversion Dam was estimated to be 20.5% and 25% using the Stage Dependent and Stage Independent Models, respectively. For more information about input and outputs of this model run see Appendix D Table 16A, Figure 15A. These survival estimates are consistent with our egg-to-fry survival performance metric for Tier 2 and3 years.

Commitment to Tier

WY 2020 was determined to be a Tier 3 year in the Water Temperature Management Plan. Tier 3 and the 2020 Temperature Management Plan's temperature targets/locations were maintained for the entire 2020 Sacramento River water temperature management season. There was no shift to a warmer tier nor were there amendments to the May 2020 water temperature management plan.

Conservation Measures

Due to concerns of a Tier 4 year during the winter of 2020, the resource agencies evaluated Livingston Stone National Fish Hatchery intervention options. In WY 2020, there was increased production at Livingston Stone National Fish Hatchery (Table 11 and Table 12). Reclamation implemented the Tier 3 consideration of intervention measures to increase winter-run Chinook salmon hatchery production at Livingston Stone National Fish Hatchery (NFH). On April 3, Reclamation, NMFS, USFWS, and CDFW met and began discussing the intervention to increase the winter run Chinook salmon hatchery production at Livingston Stone NFH. The March preliminary projections/modeling indicated a high degree of uncertainty about the ability to maintain water temperatures suitable for winter Chinook salmon spawning and egg incubation in the river, and fish biologists believed that intervention might be needed. Since the hatchery was over halfway through the broodstock collection period, the biologists' view was that a decision was urgent in order to ensure that sufficient broodstock could be collected. At that meeting, all four agencies agreed to task a technical team with developing a plan to increase hatchery production at Livingston Stone NFH, and on April 16, the agencies agreed to begin implementing the increased production plan.

Table 11. Livingston Stone National Fish Hatchery Production in WY 2020.

Release Start	Release End	CWT Tag Race	Hatchery	Release Site	CWT Number Released (Percent Marked)	Confirmed Delta Loss
3/23/2020	3/23/2020	Winter	Livingston Stone NFH	Sacramento River, Caldwell Park, Redding, CA	97,505 (100%)	0
3/10/2020	3/10/2020	Winter	Livingston Stone NFH	Sacramento River, Caldwell Park, Redding, CA	152,809 (100%)	0

Table 12. Livingston Stone National Fish Hatchery Projects in WY 2020.

Project	Females Collected	Females Spawned	Males Collected	Males Spawned	Green Eggs	Eyed Eggs	Fry
Mainstem Sacramento River	80	75	111	96	368,391	353,659	320,138
Battle Creek Jumpstart (Battle Creek Returns)	34	31	66	52	163,934	155,322	145,579*
Battle Creek Jumpstart (Captive Broodstock)	NA	136	NA	76	128,317	107,183	NA**

*Juveniles transferred to Coleman NFH on 10/7/2020
**Eyed eggs and fry transferred to Mt. Lassen Trout Farm and Coleman NFH, respectively

Discussion

Prior to the beginning of the water temperature management season, Reclamation undertook an intensive modeling effort for seasonal planning of reservoir releases using a conservative forecast. Using conservative assumptions in the initial temperature modeling contributed to conservative water temperature dependent egg mortality estimates established in the 2020 TMP, which Reclamation began implementing on May 15, 2020. As the year progressed, Reclamation incorporated actual water temperature data as it became available to refine the models. After the water temperature management season ended on October 31, 2020, Reclamation completed model hindcast evaluations to better understand the inherent model error or bias associated with the HEC-5Q model and to determine the actual water temperature dependent mortality using 2020 redd data. A hindcast evaluation helps determine how well the model could reproduce a condition such as actual downstream water temperatures and the resulting error describes how well the model performs given perfect foresight. As Figure 17, Figure 18, and Figure 19 indicate, the water temperature models overestimated the water temperatures resulting in an overestimate of water temperature dependent egg mortality, especially at Keswick Dam. When providing forecasts of water temperature dependent egg mortality for winter-run Chinook salmon, Reclamation relies on previous year's redd data and temperature data as inputs for these forecasts. When 2020 redd data

was replaced with the redd data (2007-2014) Reclamation used for forecasted water temperature dependent mortality estimates, water temperature dependent mortality was estimated to be 2.7% and 6.6% (Appendix D; Table 9A). These similar water temperature dependent mortality estimates indicate that the redd data Reclamation used for the forecasts appear to be representative of WY 2020's redd data.

Egg mortality observed in WY 2020 may have also been influenced by other factors aside from water temperature. In WY 2020, Reclamation analyzed potential early spring water temperature management prior to the onset of spawning, which showed tradeoffs with potential late-fall cold water pool benefits. Based on the forecasted Tier 3 temperature management conditions, the 2020 focus was placed on temperature management through the early fall rather than potential cooler temperatures during the spring. It is unclear what effect early spring temperature management may have had on winter-run Chinook salmon during the 2020 pre-spawn period. When temperatures are warmer than is suitable for Chinook salmon spawning, the fish are less likely to spawn in those habitats. This effect may be evaluated when considering the spring management for spawning locations. Hydrology may have also affected spawning as tributaries were drier and there was less suitable habitat to spawn in. In WY 2020, spawning distribution was generally similar to historical patterns with a slight increase in the upstream reach (Keswick Dam to ACID Dam). Proportions in the lower reaches was generally similar to historical patterns in these reaches. In WY 2020, spawning timing started in April and ended in late August; these dates indicate that winter-run Chinook salmon may spawn prior to the initiation of active temperature management and that emergence, which occurs approximately 88-90 days after egg deposition, may occur after the conclusion of active temperature management as required by the ROD. Based on the summary results described in the Fisheries section, both the spatial and temporal requirements for Shasta cold water pool management may over time lead to reduction in the spatial and temporal distribution of winter-run Chinook salmon spawning in the Upper Sacramento River. Widespread wildfire activity throughout the summer may have preserved more cold water in Shasta Lake. Smoke and haze were unusually prevalent throughout August and September and likely reduced temperature dependent mortality by dampening the effect of hot air temperature conditions on reservoir heating and downstream in-river warming.

Reclamation anticipates the NMFS December Preliminary JPE letter will show egg-to-fry survival between 10.3% - 12.5%. One factor that potentially contributed to low egg-to-fry survival this year is thiamine deficiency complex (Harder et al. 2018). During their ocean phase, adult Chinook salmon may have shifted their diets to feed on fish that have greater concentrations of thiaminase (thiamine-degrading compound). Thiamine deficiency complex in adult salmon can cause high mortality in the early life stages of their progeny (e.g., prior to emergence). During the previous two years, thiamine deficiency complex has been reported to have impacted Chinook salmon in fish hatcheries in the Central Valley (e.g., Feather River Fish Hatchery). Currently, the SacPAS Fish Model does not account for thiamine deficiency impacts on egg-to-fry survival.

Improvements

Improvements listed in this section may be evaluated as potential future updates to Shasta Lake cold water pool management, including the Shasta Cold Water Pool Guidance Document, that could assist operations in upcoming water temperature management seasons. Improvements may also be considered or evaluated by the four-year independent review panels.

Modeling Improvements

Edits were made to a single HEC-5Q model parameter in an effort to rectify these errors as simply as possible without a full model recalibration. Because Keswick Reservoir calibration was likely to be the source of the error, the relationship between Keswick Reservoir temperature and equilibrium temperature was revised so that modeled downstream temperatures closely matched historical temperatures at Keswick Dam, Clear Creek, and Ball's Ferry. Further model edits may be pursued in the future. Because the model edits were below Shasta Dam, Lake Shasta vertical temperature profile comparisons were unchanged. Revised downriver errors and graphs are shown below. Biases are reduced at Keswick Dam without increasing bias to high levels at Clear Creek and Ball's Ferry (Table 13). The time series still roughly match in pattern at each location (Figure 22 and Figure 23).

Table 13. Updated errors metrics after model edits. Error metrics used to compare modeled vertical temperature profiles for Shasta Lake and Sacramento River temperatures to 2020 observed data. Metrics include Mean Bias, Mean Average Error (MAE), Root Mean Squared Error (RMSE), and Nash-Sutcliffe Efficiency (NSE).

Name	KESWICK	CLEAR CREEK	BALLS FERRY
Mean Bias	0.4041	-0.4409	-0.5783
MAE	0.6535	0.6330	0.8193
RMSE	0.7752	0.8981	1.1111
NSE	-0.0561	0.3124	0.5571

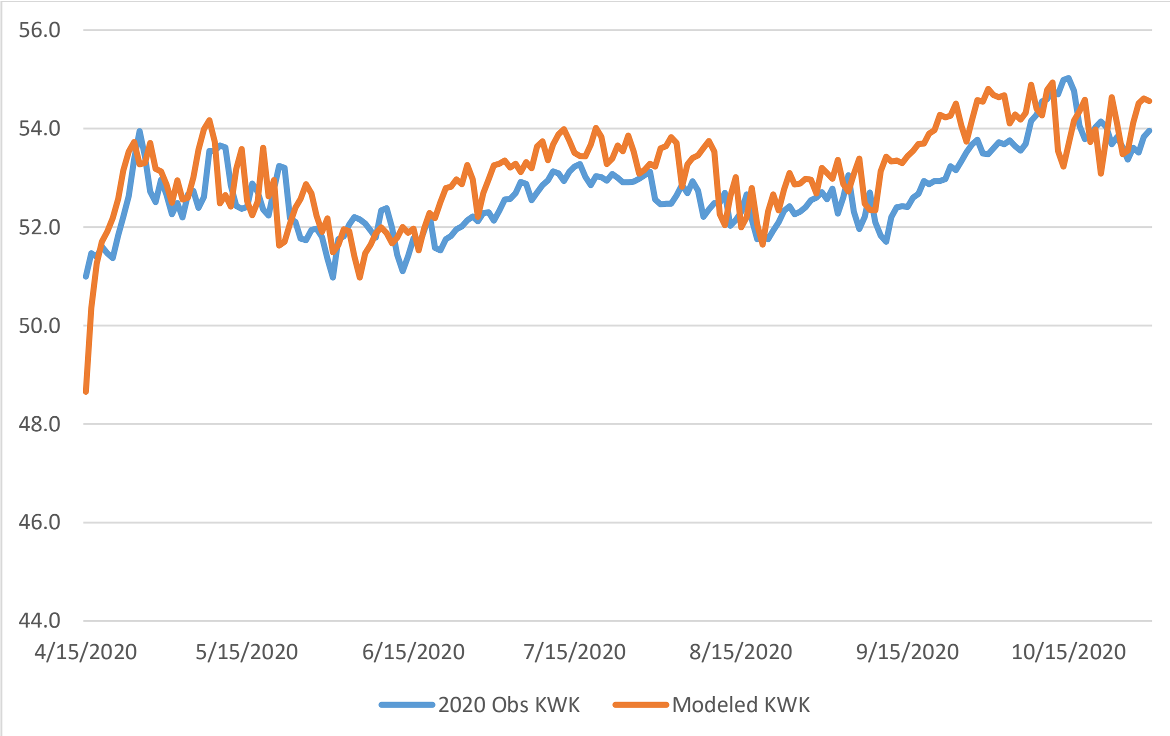

Figure 22. Updated modeled and observed water temperatures at Keswick (KWK) from 4/15/2020 - 10/31/2020.

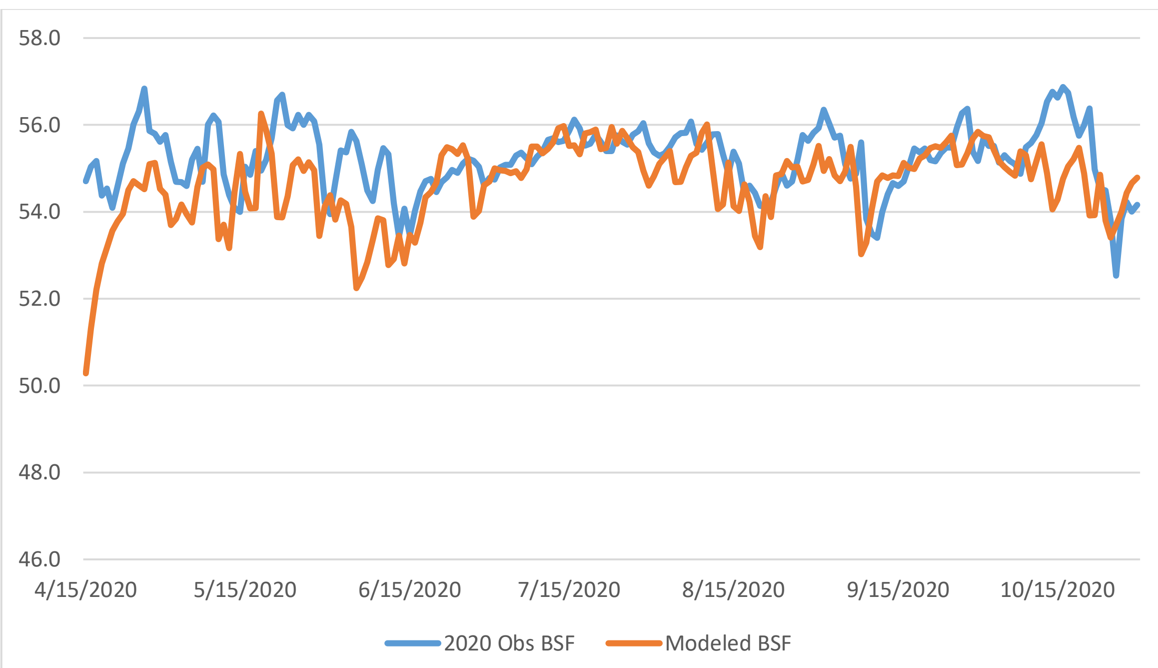

Figure 23. Updated modeled and observed water temperatures at Balls Ferry (BSF) from 4/15/2020 - 10/31/2020.

Monitoring Improvements

A suite of meteorological instruments will be deployed consistent with DWR's statewide monitoring network: California Hydrologic Data Acquisition System Stations (HyDAS) at Shasta Dam station SHS. Work is on-going and station completion is expected in 2021.

Due to reservoir dynamics, anchoring temperature monitoring devices is extremely challenging. A new anchoring system at Shasta Dam was installed in 2020 and the thermistor string re-deployed for more continuous sampling. This compliments high quality manual sampling on less frequent intervals.

Analysis Tools

Central Valley Prediction and Assessment of Salmon (CVPAS/SacPAS)
Reclamation provides funding support to the University of Washington to develop a webtool to provide information integration services. The web-based services relate fish passage to environmental conditions and provide resources for evaluating the effects of river management and environmental conditions on salmon passage and survival. These tools will be further developed to provide for a new system of forecasting in-season impacts of temperature and flow management. This system will integrate existing monitoring systems and should provide insight into the biological results and effectiveness of actions implemented as part of the Central Valley Project Improvement Act (CVPIA), including temperature management, flow management, and potentially habitat restoration.

SacPAS is publicly-accessible at: http://www.cbr.washington.edu/sacramento/

The SacPAS website includes the Fish Model, which predicts the timing and survival of juvenile salmon from spawning through smolt passage into the San Francisco Bay at Chipps Island. It links together four model systems:

1. CVTEMP model forecasts the temperature in the winter-run Chinook habitat
2. Emergence model predicts fry emergence timing and egg-to-RBDD survival
3. Migration Model predicts the movement and survival of smolts to the Delta
4. STARS model predicts the movement and survival of fish through the delta.

The current Fish Model and associated life-stage tools predict consequences of water operations on juvenile fish passage and survival. The Fish Model will be further developed with the aim of producing a more integrated system analysis and forecast system for fishes of the Central Valley. A Temperature Dependent Mortality (TDM) subteam has been formed. This team should review the input parameters in the Fish Model to determine which are best for predicting temperature dependent mortality. After the TDM subteam determines which input parameters are the best, those parameters can be saved as default parameters in the Fish Model to improve the user-friendliness of the Tool.

New features are being developed that would help evaluate performance of cold water pool management. These features include:

- Sacramento River Temperature Task Group page to organize all the information that the SRTTG would be interested in.
- Figures to depict historical migration timing of Chinook salmon.
- Upload water velocity, flow, temperatures and other data generated from physical models including CVTEMP and DMS2 when made available from collaborating agencies. For example, short-term and long-term modeled temperature data will be uploaded from the NOAA CVTEMP website.
- Real-time redd data
- RBDD Passage Model: The life segment between fry emergence and RBDD passage is critical in determining early life survival and ultimately cohort success. The current Fish Model characterizes winter-run Chinook salmon survival in this segment by a fixed background value. Fish survival and growth will be modeled to better resolve time-dependent changes in survival over the migration season. The approach will use a stochastic movement equation that characterizes the movement, growth and survival of fish from fry emergence to passage at RBDD.
  The proposed RBDD Model will link the fry emergence distribution (timing, location) to the RBDD passage distribution (size-number-frequency) by a stochastic process that characterizes the protracted arrival distribution and size-frequency distribution of fish at RBDD. The spatio-temporal distribution of fry emergence is generated by the Emergence Model, and the RBDD passage data are depicted by the daily/weekly size-frequency distributions reported by the fish monitoring program. The two distributions will be linked by four free parameters of a stochastic moment model: fish growth rate, mean and variance of fish migration velocity, and mortality rate.
- SacPAS tutorial recording to assist users in learning how to use these tools.

Conclusion and Management Summary

The 2020 Temperature Management Plan detailed a Tier 3 performance category and specified both temperature targets and compliance locations at CCR and Balls Ferry. Reclamation's hindcast temperature dependent mortality estimates ranged from 3.0% to 7.2% in WY 2020; these results indicate that the Tier 3 Upper Sacramento River Performance Metric for temperature dependent mortality were met. No need was identified by the agencies for an independent panel review for WY 2020.

Improvement recommendations to the guidance document and/or future operations that may be considered include:

- Modeling improvements to better represent water temperatures below Keswick Dam.
- Monitoring improvements with meteorological instruments and thermistor at Shasta Dam.

- Improvements to SacPAS with the development of features that may help evaluate performance of cold water pool management.

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Supporting Links

Sacramento River Temperature and Order 90-5 Compliance - https://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/sacramento_river/

SRTTG Notes - https://www.usbr.gov/mp/bdo/water-year-2020-rivertask.html

WOMT Notes – https://usbr.gov/mp/bdo/water-operations-management.html

CDFW Upper Sacramento River Basin Salmonid Monitoring Program data on CalFish - https://www.calfish.org/ProgramsData/ConservationandManagement/CDFWUpperSacRiverBasinSalmonidMonitoring/tabid/357/Agg2208_SelectTab/4/Default.aspx

SacPAS - http://www.cbr.washington.edu/sacramento/